US011969538B2

(12) **United States Patent**
Quintanar

(10) **Patent No.: US 11,969,538 B2**
(45) **Date of Patent: Apr. 30, 2024**

(54) **WOUND THERAPY SYSTEMS AND METHODS WITH MULTIPLE POWER SOURCES**

(71) Applicant: **T.J.Smith and Nephew, Limited**, Hull (GB)

(72) Inventor: **Felix Clarence Quintanar**, Hull (GB)

(73) Assignee: **T.J.Smith and Nephew, Limited**, Hull (GB)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 278 days.

(21) Appl. No.: **17/414,729**

(22) PCT Filed: **Dec. 16, 2019**

(86) PCT No.: **PCT/EP2019/085271**
§ 371 (c)(1),
(2) Date: **Jun. 16, 2021**

(87) PCT Pub. No.: **WO2020/126991**
PCT Pub. Date: **Jun. 25, 2020**

(65) **Prior Publication Data**

US 2022/0040401 A1 Feb. 10, 2022

(30) **Foreign Application Priority Data**

Dec. 21, 2018 (GB) 1820927

(51) **Int. Cl.**
A61M 1/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A61M 1/73*** (2021.05); ***A61M 1/91*** (2021.05); ***A61M 1/915*** (2021.05); ***A61M 1/916*** (2021.05);
(Continued)

(58) **Field of Classification Search**
CPC A61F 13/00068; A61F 13/0216; A61M 2205/3344; A61M 1/90; A61M 1/95;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,599,639 A * 8/1971 Spotz A61M 1/80 604/245
3,896,802 A 7/1975 Williams
(Continued)

FOREIGN PATENT DOCUMENTS

CN 105232229 A 1/2016
CN 105395184 A 3/2016
(Continued)

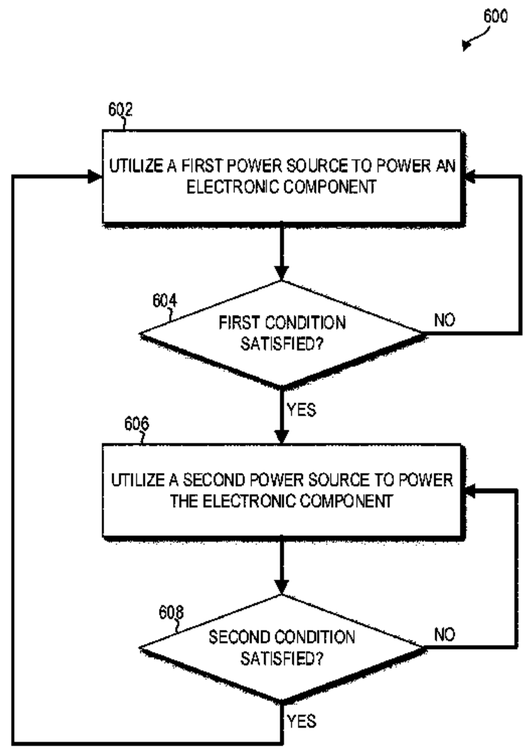
OTHER PUBLICATIONS

Aubakir B., et al., "Vital Sign Monitoring Utilizing Eulerian Video Magnification and Thermography," 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Aug. 16, 2016, pp. 3527-3530 (4 pages).
(Continued)

Primary Examiner — Leslie A Lopez
Assistant Examiner — Seth Han
(74) *Attorney, Agent, or Firm* — Knobbe, Martens, Olson & Bear, LLP

(57) **ABSTRACT**

The present disclosure provides in part improved apparatuses, systems, and methods for providing therapy to a wound. A system can include a first power source configured to power an electronic component and a second power source configured to power the electronic component in place of the first power source. Responsive to a first condition, the second power source can power the electronic component in place of the first power source. In some cases, the system can include a pressure source that is configured to provide negative pressure to a wound dressing positioned
(Continued)



over a wound. The wound dressing can support the first power source or the second power source.

21 Claims, 18 Drawing Sheets

(52) **U.S. Cl.**
CPC ***A61M 1/95*** (2021.05); ***A61M 1/96*** (2021.05); *A61M 1/962* (2021.05); *A61M 1/985* (2021.05); *A61M 2205/16* (2013.01); *A61M 2205/8206* (2013.01); *A61M 2205/8237* (2013.01)

(58) **Field of Classification Search**
CPC A61M 1/96; A61M 1/962; A61M 1/966; A61M 2205/8206; A61M 2205/82; A61M 2205/8212; A61M 1/73; A61B 2560/0204; A61B 2560/0209; H02J 7/0013; H02J 7/0025; H02J 7/0024; H02J 7/0014
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,334,530	A	6/1982	Hassell	
5,090,410	A	2/1992	Saper et al.	
5,177,371	A *	1/1993	Faulk	H02J 9/06 340/636.15
5,253,654	A	10/1993	Thomas et al.	
5,635,201	A	6/1997	Fabo	
5,642,096	A	6/1997	Leyerer et al.	
5,678,448	A	10/1997	Fullen et al.	
5,690,610	A	11/1997	Ito et al.	
5,836,990	A	11/1998	Li	
6,095,992	A	8/2000	Augustine	
6,178,342	B1	1/2001	Borgos et al.	
6,381,482	B1	4/2002	Jayaraman et al.	
6,517,484	B1	2/2003	Wilk et al.	
6,551,252	B2	4/2003	Sackner et al.	
6,731,987	B1	5/2004	McAdams et al.	
7,077,832	B2	7/2006	Fleischmann	
7,088,591	B2	8/2006	Kishimoto et al.	
7,201,063	B2	4/2007	Taylor	
7,206,623	B2	4/2007	Blank et al.	
7,289,205	B2	10/2007	Yaroslavsky et al.	
7,316,652	B2	1/2008	Dalgaard et al.	
7,429,255	B2	9/2008	Thompson	
7,520,875	B2	4/2009	Bernabei	
7,521,292	B2	4/2009	Rogers et al.	
7,569,742	B2	8/2009	Haggstrom et al.	
7,625,117	B2	12/2009	Haslett et al.	
7,687,678	B2	3/2010	Jacobs	
7,846,141	B2	12/2010	Weston	
7,877,866	B1	2/2011	Greenberg et al.	
7,884,258	B2	2/2011	Boehringer et al.	
7,904,133	B2	3/2011	Gehman et al.	
7,922,676	B2	4/2011	Daskal et al.	
7,942,869	B2	5/2011	Houbolt et al.	
7,945,302	B2	5/2011	McAdams	
8,019,401	B1	9/2011	Smith et al.	
8,032,210	B2	10/2011	Finneran et al.	
8,060,174	B2	11/2011	Simpson et al.	
8,079,247	B2	12/2011	Russell et al.	
8,111,165	B2	2/2012	Ortega et al.	
8,116,841	B2	2/2012	Bly et al.	
8,182,425	B2	5/2012	Stamatas et al.	
8,238,996	B2	8/2012	Burnes et al.	
8,241,231	B2	8/2012	Bausewein et al.	
8,332,053	B1	12/2012	Patterson et al.	
8,333,874	B2	12/2012	Currie	
8,366,692	B2	2/2013	Weston et al.	
8,480,641	B2	7/2013	Jacobs	
8,579,872	B2	11/2013	Coulthard et al.	
8,644,911	B1	2/2014	Panasyuk et al.	
8,663,106	B2	3/2014	Stivoric et al.	
8,682,442	B2	3/2014	McAdams	
8,783,948	B2	7/2014	Panda et al.	
8,788,009	B2	7/2014	Greene et al.	
8,800,386	B2	8/2014	Taylor	
8,818,478	B2	8/2014	Scheffler et al.	
8,848,187	B2	9/2014	Uematsu et al.	
8,894,590	B2	11/2014	Lamoise et al.	
8,925,392	B2	1/2015	Esposito et al.	
8,934,957	B2	1/2015	Dias et al.	
8,934,965	B2	1/2015	Rogers et al.	
8,943,897	B2	2/2015	Beauvais et al.	
8,948,839	B1	2/2015	Longinotti-Buitoni et al.	
8,997,588	B2	4/2015	Taylor	
9,000,251	B2	4/2015	Murphy et al.	
9,042,075	B2	5/2015	Borini et al.	
9,192,531	B2	11/2015	Wu	
9,220,455	B2	12/2015	Sarrafzadeh et al.	
9,226,402	B2	12/2015	Hsu	
9,282,897	B2	3/2016	Ross, Jr. et al.	
9,314,175	B2	4/2016	Jacofsky et al.	
9,320,473	B2	4/2016	Shuler	
9,372,123	B2	6/2016	Li et al.	
9,378,450	B1	6/2016	Mei et al.	
9,386,947	B2	7/2016	Johnson	
9,393,354	B2	7/2016	Freedman et al.	
9,402,988	B2	8/2016	Buchanan et al.	
9,408,573	B2	8/2016	Welch et al.	
9,427,179	B2	8/2016	Mestrovic et al.	
9,439,599	B2	9/2016	Thompson et al.	
9,483,726	B2	11/2016	Mei et al.	
9,494,474	B2	11/2016	Servati et al.	
9,511,215	B2	12/2016	Skiba	
9,516,758	B2	12/2016	Arora et al.	
9,526,439	B2	12/2016	Connelly et al.	
9,554,484	B2	1/2017	Rogers et al.	
9,572,507	B2	2/2017	Moore et al.	
9,582,072	B2	2/2017	Connor	
9,585,620	B2	3/2017	Paquet et al.	
9,587,991	B2	3/2017	Padiy	
9,592,007	B2	3/2017	Nuovo et al.	
9,603,560	B2	3/2017	Monty et al.	
9,610,388	B2	4/2017	Aceto et al.	
9,613,911	B2	4/2017	Rogers et al.	
9,629,584	B2	4/2017	Macia Barber et al.	
9,675,238	B2	6/2017	Iida et al.	
9,687,195	B2	6/2017	Sims et al.	
9,717,565	B2	8/2017	Blair	
9,829,471	B2	11/2017	Hammond et al.	
9,907,103	B2	2/2018	Chen et al.	
10,004,643	B2	6/2018	Luckemeyer et al.	
10,046,096	B2	8/2018	Askem et al.	
10,080,524	B1	9/2018	Xi	
10,086,117	B2	10/2018	Locke et al.	
10,117,705	B2	11/2018	Chernov et al.	
10,152,789	B2	12/2018	Carnes et al.	
10,182,740	B2	1/2019	Tonar et al.	
10,207,031	B2	2/2019	Toth	
10,209,213	B2	2/2019	Kang et al.	
10,285,620	B2	5/2019	Jung et al.	
10,321,862	B2	6/2019	Dalene et al.	
10,463,773	B2	11/2019	Haggstrom et al.	
10,687,984	B2	6/2020	Rovaniemi	
10,857,038	B2	12/2020	Zamierowski et al.	
11,026,847	B2	6/2021	Piotrowski et al.	
11,647,922	B2	5/2023	Scherer	
2002/0016536	A1	2/2002	Benni	
2002/0135752	A1	9/2002	Sokolov et al.	
2003/0033032	A1	2/2003	Lind et al.	
2003/0208148	A1	11/2003	Sullivan	
2003/0210810	A1	11/2003	Gee, Jr. et al.	
2003/0216630	A1	11/2003	Jersey-Willuhn et al.	
2004/0230132	A1	11/2004	Shehada	
2005/0088832	A1	4/2005	Su et al.	
2005/0240107	A1	10/2005	Alfano et al.	
2005/0280531	A1	12/2005	Fadem et al.	
2006/0052678	A1	3/2006	Drinan et al.	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0058690	A1	3/2006	Bartnik et al.	
2006/0181791	A1	8/2006	Van Beek et al.	
2006/0234383	A1	10/2006	Gough	
2006/0241495	A1	10/2006	Kurtz	
2007/0040449	A1*	2/2007	Spurlin	H02J 7/342 307/64
2007/0055209	A1	3/2007	Patel et al.	
2007/0173892	A1	7/2007	Fleischer et al.	
2007/0191754	A1	8/2007	Aali	
2007/0219597	A1*	9/2007	Kamen	A61M 5/142 128/903
2007/0260421	A1	11/2007	Berner, Jr. et al.	
2007/0293748	A1	12/2007	Engvall et al.	
2008/0081973	A1	4/2008	Hoarau	
2008/0167535	A1	7/2008	Stivoric et al.	
2008/0243079	A1*	10/2008	Wooley	A61M 5/14244 324/426
2008/0258717	A1	10/2008	Igney et al.	
2008/0269673	A1*	10/2008	Butoi	A61M 5/14244 604/67
2008/0276684	A1	11/2008	Goldbach	
2008/0287747	A1	11/2008	Mestrovic et al.	
2008/0319282	A1	12/2008	Tran	
2008/0319283	A1	12/2008	Cotton et al.	
2009/0124988	A1	5/2009	Coulthard	
2009/0149800	A1	6/2009	Durand	
2009/0177051	A1	7/2009	Arons et al.	
2009/0177110	A1	7/2009	Lyden et al.	
2009/0209830	A1	8/2009	Nagle et al.	
2009/0234206	A1	9/2009	Gaspard et al.	
2009/0245601	A1	10/2009	Cohen et al.	
2010/0022990	A1	1/2010	Karpowicz et al.	
2010/0025831	A1	2/2010	Yamazaki et al.	
2010/0166252	A1	7/2010	Ahmed et al.	
2010/0168727	A1	7/2010	Hancock et al.	
2010/0191078	A1*	7/2010	Yodfat	A61M 5/14248 604/131
2010/0244780	A1*	9/2010	Turner	A61M 1/96 320/162
2010/0305473	A1	12/2010	Yuzhakov	
2011/0004088	A1	1/2011	Grossman	
2011/0015591	A1	1/2011	Hanson et al.	
2011/0054283	A1	3/2011	Shuler	
2011/0130697	A1	6/2011	Nagle et al.	
2011/0140703	A1	6/2011	Chiao et al.	
2011/0190639	A1	8/2011	Peltie et al.	
2011/0208161	A1*	8/2011	Ivri	A61K 31/4468 604/257
2011/0218384	A1*	9/2011	Bachman	A61M 60/411 361/679.01
2011/0218757	A1	9/2011	Callsen et al.	
2011/0242532	A1	10/2011	McKenna	
2011/0245682	A1	10/2011	Robinson et al.	
2011/0301441	A1	12/2011	Bandic et al.	
2012/0029306	A1	2/2012	Paquet et al.	
2012/0029307	A1	2/2012	Paquet et al.	
2012/0029410	A1	2/2012	Koenig et al.	
2012/0035562	A1	2/2012	Locke et al.	
2012/0109083	A1*	5/2012	Coulthard	A61M 1/962 604/319
2012/0112347	A1	5/2012	Eckhardt et al.	
2012/0165717	A1	6/2012	Al Khaburi	
2012/0190956	A1	7/2012	Connolly	
2012/0190989	A1	7/2012	Kaiser et al.	
2012/0265120	A1	10/2012	Beisang, III et al.	
2012/0271265	A1	10/2012	Langdon	
2012/0277559	A1	11/2012	Kohl-Bareis et al.	
2012/0316538	A1	12/2012	Heiser et al.	
2012/0330252	A1	12/2012	Stokes et al.	
2013/0041235	A1	2/2013	Rogers et al.	
2013/0064772	A1	3/2013	Swiss et al.	
2013/0121544	A1	5/2013	Sarrafzadeh et al.	
2013/0123722	A1	5/2013	Pratt et al.	
2013/0151223	A1	6/2013	Zamierowski et al.	
2013/0200268	A1	8/2013	Rafferty et al.	
2013/0261409	A1	10/2013	Pathak et al.	
2013/0271278	A1	10/2013	Duesterhoft et al.	
2013/0274563	A1	10/2013	Duesterhoft et al.	
2013/0274629	A1	10/2013	Duesterhoft et al.	
2013/0317367	A1	11/2013	Shuler	
2014/0012108	A1	1/2014	McPeak	
2014/0018637	A1	1/2014	Bennett et al.	
2014/0024905	A1	1/2014	Sarrafzadeh et al.	
2014/0031663	A1	1/2014	Gallego et al.	
2014/0072190	A1	3/2014	Wu et al.	
2014/0075658	A1	3/2014	McGuin	
2014/0107495	A1	4/2014	Marinelli et al.	
2014/0107498	A1	4/2014	Bower et al.	
2014/0147611	A1	5/2014	Ackerman, Jr.	
2014/0203797	A1	7/2014	Stivoric et al.	
2014/0206947	A1	7/2014	Isserow et al.	
2014/0232516	A1	8/2014	Stivoric et al.	
2014/0235166	A1	8/2014	Molettiere et al.	
2014/0243709	A1	8/2014	Gibson et al.	
2014/0296749	A1	10/2014	Reid, Jr. et al.	
2014/0298927	A1	10/2014	Allin et al.	
2014/0298928	A1	10/2014	Duesterhoft et al.	
2014/0303463	A1	10/2014	Robinson et al.	
2014/0324120	A1	10/2014	Bogie et al.	
2014/0340857	A1	11/2014	Hsu et al.	
2014/0343478	A1	11/2014	Brennan et al.	
2014/0350882	A1	11/2014	Everett et al.	
2015/0018792	A1	1/2015	Marsiquet et al.	
2015/0025343	A1	1/2015	Gareau et al.	
2015/0138330	A1	5/2015	Krishnamoorthi	
2015/0141767	A1	5/2015	Rogers et al.	
2015/0148760	A1	5/2015	Dodd et al.	
2015/0150479	A1	6/2015	Yoshino et al.	
2015/0174304	A1*	6/2015	Askem	A61F 13/00042 604/319
2015/0182166	A1	7/2015	Evans et al.	
2015/0202353	A1	7/2015	Daughtery	
2015/0223716	A1	8/2015	Korkala et al.	
2015/0257644	A1	9/2015	Cao	
2015/0265191	A1	9/2015	Harding et al.	
2015/0292968	A1	10/2015	Vogt et al.	
2015/0313476	A1	11/2015	Pisani et al.	
2015/0313533	A1	11/2015	Rapp et al.	
2015/0327777	A1	11/2015	Kostic et al.	
2015/0335254	A1	11/2015	Fastert et al.	
2015/0335287	A1	11/2015	Neuman et al.	
2015/0335288	A1	11/2015	Toth et al.	
2015/0351970	A1	12/2015	Dagger et al.	
2015/0359485	A1	12/2015	Berg et al.	
2015/0374309	A1	12/2015	Farkas et al.	
2016/0015962	A1	1/2016	Shokoueinejad Maragheh et al.	
2016/0022223	A1	1/2016	Grundfest et al.	
2016/0029900	A1	2/2016	LaPlante et al.	
2016/0030132	A1	2/2016	Cheung et al.	
2016/0038045	A1	2/2016	Shapiro	
2016/0038083	A1	2/2016	Ding et al.	
2016/0051147	A1	2/2016	Cohen et al.	
2016/0058380	A1	3/2016	Lee et al.	
2016/0066854	A1	3/2016	Mei et al.	
2016/0069743	A1	3/2016	McQuilkin et al.	
2016/0074234	A1	3/2016	Abichandani et al.	
2016/0081580	A1	3/2016	Bergelin et al.	
2016/0081601	A1	3/2016	Ballam et al.	
2016/0089483	A1*	3/2016	Chen	A61M 60/585 600/17
2016/0100790	A1	4/2016	Cantu et al.	
2016/0100987	A1	4/2016	Hartwell et al.	
2016/0101282	A1	4/2016	Bergelin et al.	
2016/0129469	A1	5/2016	Kulinsky et al.	
2016/0143534	A1	5/2016	Hyde et al.	
2016/0157779	A1	6/2016	Baxi et al.	
2016/0165719	A1	6/2016	Li et al.	
2016/0213269	A1	7/2016	Lam et al.	
2016/0228049	A1	8/2016	Nackaerts et al.	
2016/0232807	A1	8/2016	Ghaffari et al.	
2016/0242331	A1	8/2016	Park et al.	
2016/0249810	A1	9/2016	Darty et al.	
2016/0262672	A1	9/2016	Hammond et al.	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2016/0262687	A1	9/2016	Vaidyanathan et al.	
2016/0270700	A1	9/2016	Baxi	
2016/0287177	A1	10/2016	Huppert et al.	
2016/0302729	A1	10/2016	Starr et al.	
2016/0310023	A1	10/2016	Chachisvilis et al.	
2016/0317057	A1	11/2016	Li et al.	
2016/0331257	A1*	11/2016	Baumann	G16H 40/67
2016/0331263	A1	11/2016	Cailler et al.	
2016/0331322	A1	11/2016	Son et al.	
2016/0338591	A1	11/2016	Lachenbruch et al.	
2016/0354001	A1	12/2016	Buckley et al.	
2016/0367189	A1	12/2016	Aimone et al.	
2016/0367192	A1	12/2016	Iyengar et al.	
2016/0367406	A1	12/2016	Barnett	
2017/0000407	A1	1/2017	Saxby et al.	
2017/0007853	A1	1/2017	Alford et al.	
2017/0027498	A1	2/2017	Larson et al.	
2017/0079740	A1	3/2017	Hufnagel et al.	
2017/0086519	A1	3/2017	Vigano' et al.	
2017/0086709	A1	3/2017	Khine et al.	
2017/0095208	A1	4/2017	Oberleitner et al.	
2017/0146474	A1	5/2017	Bedell et al.	
2017/0156594	A1	6/2017	Stivoric et al.	
2017/0156621	A1	6/2017	Bettinger et al.	
2017/0156658	A1	6/2017	Maharbiz et al.	
2017/0164865	A1	6/2017	Rafferty et al.	
2017/0164876	A1	6/2017	Hyde et al.	
2017/0172439	A1	6/2017	Zhu et al.	
2017/0202711	A1	7/2017	Cernasov et al.	
2017/0224271	A1	8/2017	Lachenbruch et al.	
2017/0231015	A1	8/2017	Jang et al.	
2017/0258972	A1	9/2017	Weston	
2017/0319075	A1	11/2017	Homan et al.	
2017/0326004	A1	11/2017	Long et al.	
2017/0354810	A1*	12/2017	O'Brien, III	A61N 1/40
2017/0367644	A1	12/2017	Sharman et al.	
2018/0008177	A1	1/2018	Shimuta et al.	
2018/0055359	A1	3/2018	Shamim et al.	
2018/0055697	A1	3/2018	Mihali et al.	
2018/0056087	A1	3/2018	Ribeiro et al.	
2018/0070880	A1	3/2018	Trembly et al.	
2018/0074547	A1	3/2018	Smadi et al.	
2018/0116877	A1	5/2018	Ineichen	
2018/0132287	A1	5/2018	Cheng et al.	
2018/0192514	A1	7/2018	Seo	
2018/0200414	A1	7/2018	Askem et al.	
2018/0206758	A1	7/2018	Feldkamp et al.	
2018/0235484	A1	8/2018	Mozdzierz	
2018/0250458	A1*	9/2018	Petersen	A61M 60/178
2018/0296397	A1	10/2018	Askem et al.	
2019/0021911	A1	1/2019	Askem et al.	
2019/0060126	A1	2/2019	Ribble et al.	
2019/0076298	A1	3/2019	Quintanar et al.	
2019/0083025	A1	3/2019	Aung et al.	
2019/0133812	A1	5/2019	Seres et al.	
2019/0159938	A1	5/2019	Askem et al.	
2019/0175098	A1	6/2019	Burns	
2019/0192066	A1	6/2019	Schoess et al.	
2019/0231939	A1	8/2019	Askem et al.	
2019/0290496	A1	9/2019	Brownhill et al.	
2019/0374387	A1	12/2019	Ribble et al.	
2020/0054218	A1	2/2020	Xi	
2020/0078482	A1	3/2020	Yoon et al.	
2020/0078499	A1	3/2020	Gadde et al.	
2020/0100711	A1	4/2020	Choudhury et al.	
2020/0147407	A1	5/2020	Efremkin	
2020/0281512	A1	9/2020	Grubb et al.	
2020/0281513	A1	9/2020	Grubb et al.	
2020/0281529	A1	9/2020	Grubb et al.	
2020/0289346	A1	9/2020	Hansen et al.	
2020/0330258	A1	10/2020	Hansen et al.	
2020/0360547	A1	11/2020	Smith et al.	
2021/0137446	A1	5/2021	Brownhill et al.	
2021/0212855	A1	7/2021	Hansen et al.	
2022/0079814	A1	3/2022	Chen et al.	

FOREIGN PATENT DOCUMENTS

CN	106102322	A	11/2016
CN	109350362	A	2/2019
DE	102012211015	A1	1/2014
DE	102013013013	A1	2/2015
EP	2454990	A2	5/2012
EP	2565630	A1	3/2013
EP	2990064	A1	3/2016
EP	3187201	A1	7/2017
EP	3231478	A1	10/2017
EP	3409190	A1	12/2018
EP	3499510	A1	6/2019
EP	3837520	A1	6/2021
GB	1476894	A	6/1977
GB	2316171	A	2/1998
GB	2563602	A	12/2018
JP	2009225863	A	10/2009
KR	20120119523	A	10/2012
KR	101224629	B1	1/2013
KR	20140024743	A	3/2014
KR	20140058041	A	5/2014
KR	20160071044	A	6/2016
KR	20190105898	A	9/2019
NL	1027236	C2	4/2006
WO	WO-9632082	A1	10/1996
WO	WO-0021433	A1	4/2000
WO	WO-0043046	A2	7/2000
WO	WO-03067229	A1	8/2003
WO	WO-2006041997	A2	4/2006
WO	WO-2006122169	A2	11/2006
WO	WO-2007030379	A2	3/2007
WO	WO-2008006150	A1	1/2008
WO	WO-2008010604	A1	1/2008
WO	WO-2009052607	A1	4/2009
WO	WO-2009120951	A2	10/2009
WO	WO-2009141777	A1	11/2009
WO	WO-2010020919	A1	2/2010
WO	WO-2010105053	A2	9/2010
WO	WO-2011082420	A1	7/2011
WO	WO-2011123848	A1	10/2011
WO	WO-2012141999	A1	10/2012
WO	WO-2013026999	A1	2/2013
WO	WO-2013044226	A2	3/2013
WO	WO-2014036577	A1	3/2014
WO	WO-2014116816	A1	7/2014
WO	WO-2015112095	A1	7/2015
WO	WO-2015168720	A1	11/2015
WO	WO-2016025438	A1	2/2016
WO	WO-2016030752	A1	3/2016
WO	WO-2016058032	A1	4/2016
WO	WO-2016073777	A1	5/2016
WO	WO-2016100218	A1	6/2016
WO	WO-2016109744	A1	7/2016
WO	WO-2016110564	A1	7/2016
WO	WO-2016187136	A1	11/2016
WO	WO-2016205872	A1	12/2016
WO	WO-2016205881	A1	12/2016
WO	WO-2017021006	A1	2/2017
WO	WO-2017021965	A2	2/2017
WO	WO-2017033058	A1	3/2017
WO	WO-2017037479	A1	3/2017
WO	WO-2017041014	A1	3/2017
WO	WO-2017041385	A1	3/2017
WO	WO-2017041386	A1	3/2017
WO	WO-2017041387	A1	3/2017
WO	WO-2017119996	A1	7/2017
WO	WO-2017205728	A1	11/2017
WO	WO-2017214188	A1	12/2017
WO	WO-2018035612	A1	3/2018
WO	WO-2018060417	A1	4/2018
WO	WO-2018064569	A1	4/2018
WO	WO-2018115461	A1	6/2018
WO	WO-2018144938	A1	8/2018
WO	WO-2018144941	A1	8/2018
WO	WO-2018144943	A1	8/2018
WO	WO-2018144946	A1	8/2018
WO	WO-2018185138	A1	10/2018
WO	WO-2018189265	A1	10/2018

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

WO	WO-2018209090	A1	11/2018
WO	WO-2018210692	A1	11/2018
WO	WO-2018211458	A1	11/2018
WO	WO-2018234443	A1	12/2018
WO	WO-2019020550	A2	1/2019
WO	WO-2019020551	A1	1/2019
WO	WO-2019020666	A1	1/2019
WO	WO-2019030384	A2	2/2019
WO	WO-2019048624	A1	3/2019
WO	WO-2019048626	A1	3/2019
WO	WO-2019048638	A1	3/2019
WO	WO-2019063481	A1	4/2019
WO	WO-2019063488	A2	4/2019
WO	WO-2019067264	A1	4/2019
WO	WO-2019072531	A1	4/2019
WO	WO-2019076967	A2	4/2019
WO	WO-2019096828	A1	5/2019
WO	WO-2019140441	A2	7/2019
WO	WO-2019140444	A1	7/2019
WO	WO-2019140448	A1	7/2019
WO	WO-2019140449	A1	7/2019
WO	WO-2019193141	A1	10/2019
WO	WO-2019216883	A1	11/2019
WO	WO-2019230183	A1	12/2019
WO	WO-2019238180	A1	12/2019
WO	WO-2019238181	A1	12/2019
WO	WO-2019238182	A1	12/2019
WO	WO-2019238195	A1	12/2019
WO	WO-2019238196	A1	12/2019
WO	WO-2019238197	A1	12/2019
WO	WO-2019238198	A1	12/2019
WO	WO-2020002416	A1	1/2020
WO	WO-2020043806	A1	3/2020
WO	WO-2020139541	A1	7/2020
WO	WO-2020157103	A1	8/2020
WO	WO-2020159677	A1	8/2020
WO	WO-2020167547	A1	8/2020
WO	WO-2020242876	A1	12/2020
WO	WO-2021059209	A1	4/2021

OTHER PUBLICATIONS

Bandodkar A.J., et al., "Battery-Free, Skin-Interfaced Microfluidic/Electronic Systems for Simultaneous Electrochemical, Colorimetric and Volumetric Analysis of Sweat," Science Advances, vol. 5 (1), Jan. 18, 2019, retrieved from http://advances.sciencemag.org/content/5/1/eaav3294, 16 pages.

Cauwe M., et al., "Technology Development for a Low-Cost, Roll-to-Roll Chip Embedding Solution Based on PET Foils," 18th European Microelectronics and Packaging Conference (EMPC), IEEE, Sep. 12, 2011, 6 pages.

Farooqui M.F., et al., "Low Cost Inkjet Printed Smart Bandage for Wireless Monitoring of Chronic Wounds," Scientific Reports, vol. 6, Jun. 29, 2016, 14 pages.

Geng Y., et al., "A Hybrid Low Power Biopatch for Body Surface Potential Measurement," IEEE Journal of Biomedical and Health Informatics, vol. 17, No. 3, May 1, 2013, pp. 591-599.

Iannetta Jr. R.A., et al., "Successful Case Histories of Polymer Based Circuitry on Flexible Film Substrates," Electro/94 International Conference Proceedings Combined Volumes, IEEE, XP010149465, May 10-12, 1994, pp. 885-889.

International Search Report and Written Opinion for Application No. PCT/EP2019/085271, dated Mar. 27, 2020, 12 pages.

Jinto G., et al., "Reliability of Plastic-Encapsulated Electronic Components in Supersaturated Steam Environments," IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 5 (10), Oct. 2015, pp. 1423-1431.

Little Miss Plasters, kidstravelclub.co.uk., retrieved from http://www.kidstravelclub.co.uk/little-miss-girls-childrens-plasters on Aug. 26, 2016, 2 pages.

Lu B., et al., "A Study of the Autofluorescence of Parylene Materials for μTAS Applications," Lab on Chip, vol. 10 (14), Jul. 2010, pp. 1826-1834.

McLeod A.J., et al., "Motion Magnification for Endoscopic Surgery," Progress in Biomedical Optics and Imaging, SPIE—International Society for Optical Engineering, Mar. 12, 2014, vol. 9036, 8 pages.

Mostafalu P., et al., "Wireless Flexible Smart Bandage for Continuous Monitoring of Wound Oxygenation," IEEE Transactions on Biomedical Circuits and Systems, vol. 9 (5), Oct. 2015, pp. 670-677 (8 pages).

Narusawa H., "The Corona Discharge Causes Short Destruction that had Bad Influence on a Power Switching Circuit," Adphox Corporation, Jan. 1, 2009, retrieved from http://www.adphox.co.jp/keisokuki/ke-english-corona/CORONA_DISCHARGE_EN.pdf, 12 pages.

Raviglione A., et al., "Real-Time Smart Textile-Based System to Monitor Pressure Offloading of Diabetic Foot Ulcers," Journal of Diabetes Science and Technology, vol. 11 (5), Sep. 2017, pp. 894-898.

Rose D.P., et al., "Adhesive RFID Sensor Patch for Monitoring of Sweat Electrolytes," IEEE Transactions on Biomedical Engineering, vol. 62 (6), Jun. 2015, first published on Nov. 11, 2015, pp. 1457-1465.

Wakita J., et al., "Variations in Optical Absorption and Fluorescence Spectra for Polyimide Thin Films Caused by Structural Isomerism," Journal of Photopolymer Science and Technology, Jan. 1, 2003, 1 page.

Willis B., "Conformal Coating Inspection & Coating Faults," Vision Engineering, Jul. 21, 2016, retrieved from http://www.visioneng.com/wp-content/uploads/2017/11/Conformal-Coating-Inspection-and-Defects.21JUL16.pdf, 35 pages.

Willis B., "Guide to Conformal Coating & Cleaning Defects Contents," Mar. 1, 2014, retrieved from http://coatingguide.smartgroup.org/Files%20pdf/Coating%20Defects%20V2%2014March2014.pdf, vol. 1, 31 pages.

International Preliminary Report on Patentability for Application No. PCT/EP2019/085271, dated Jul. 1, 2021, 9 pages.

Mehmood N., et al., "Applications of Modern Sensors and Wireless Technology In Effective Wound Management: Modern Sensors and Wireless Technology," Journal of Biomedical Materials Research Part B, vol. 102, May 1, 2014, XP055739544, pp. 885-895.

* cited by examiner

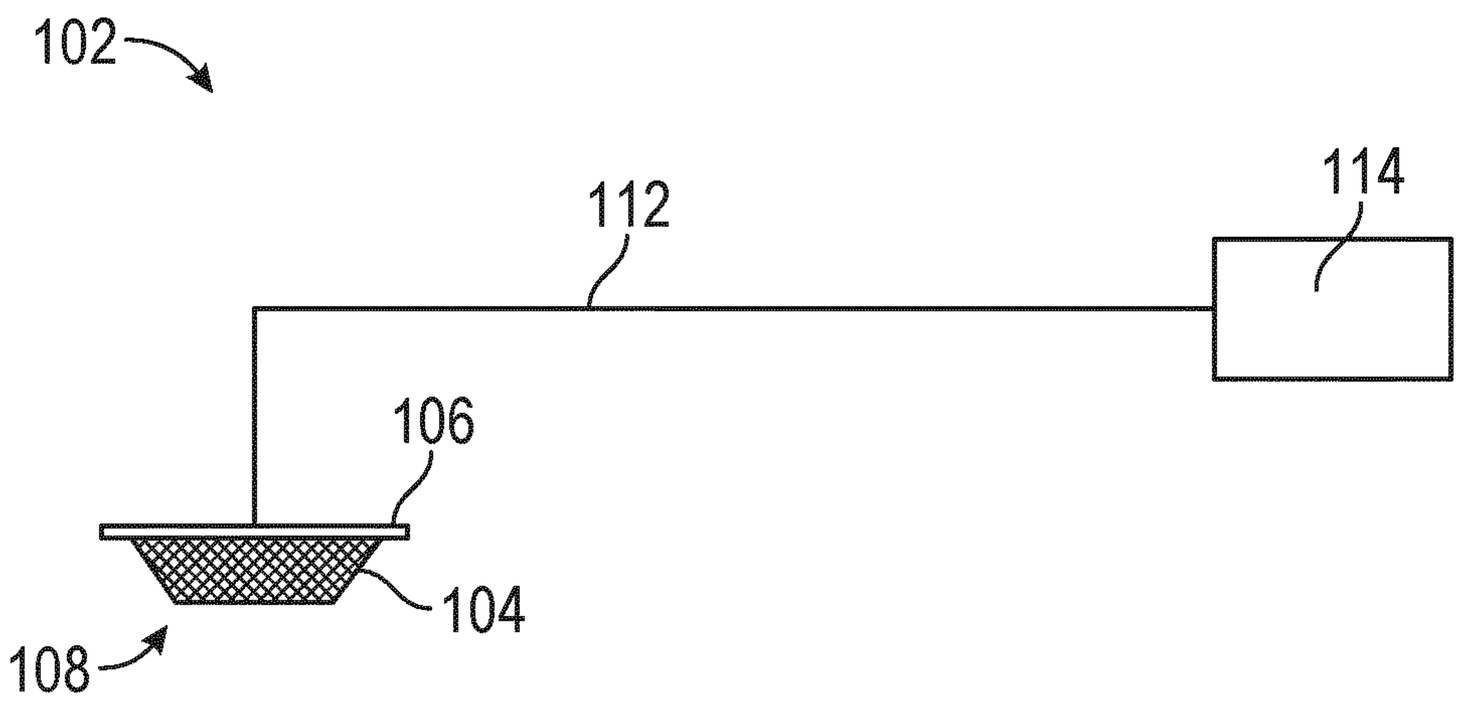

102
112
114
106
104
108

FIG. 1A

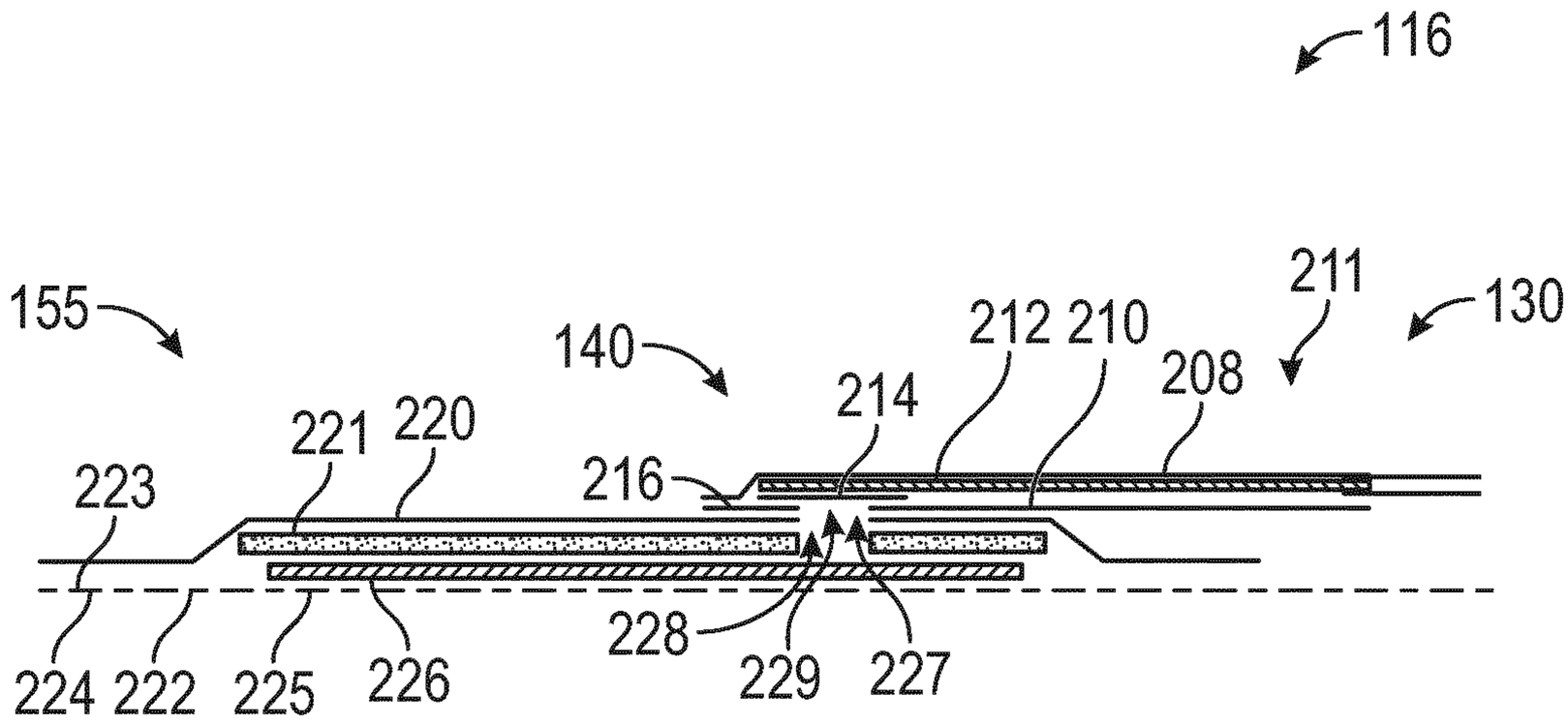

116
155
140
211
130
212
210
208
214
221
220
223
216
224
222
225
226
228
229
227

FIG. 1B

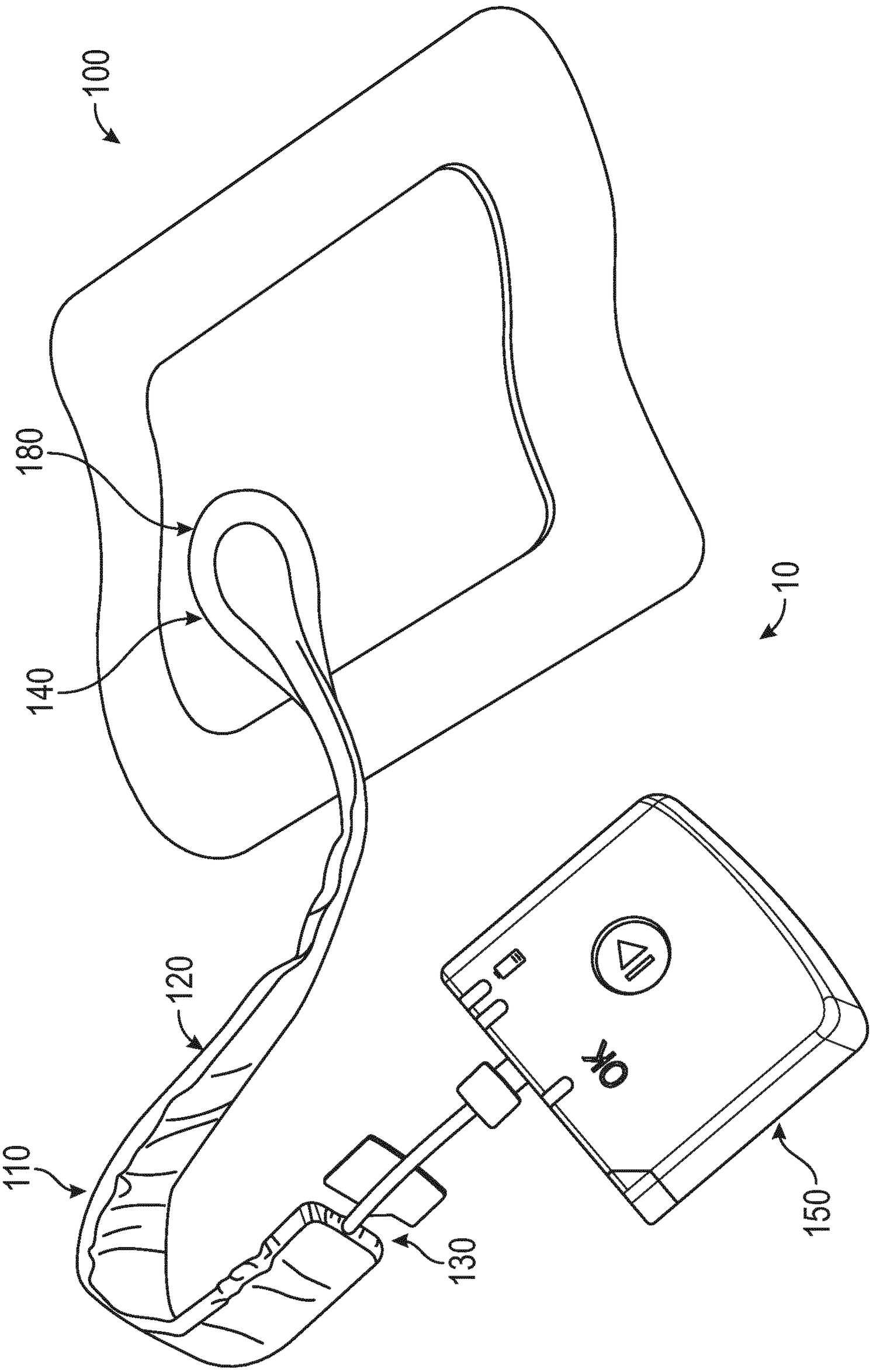


FIG. 1C

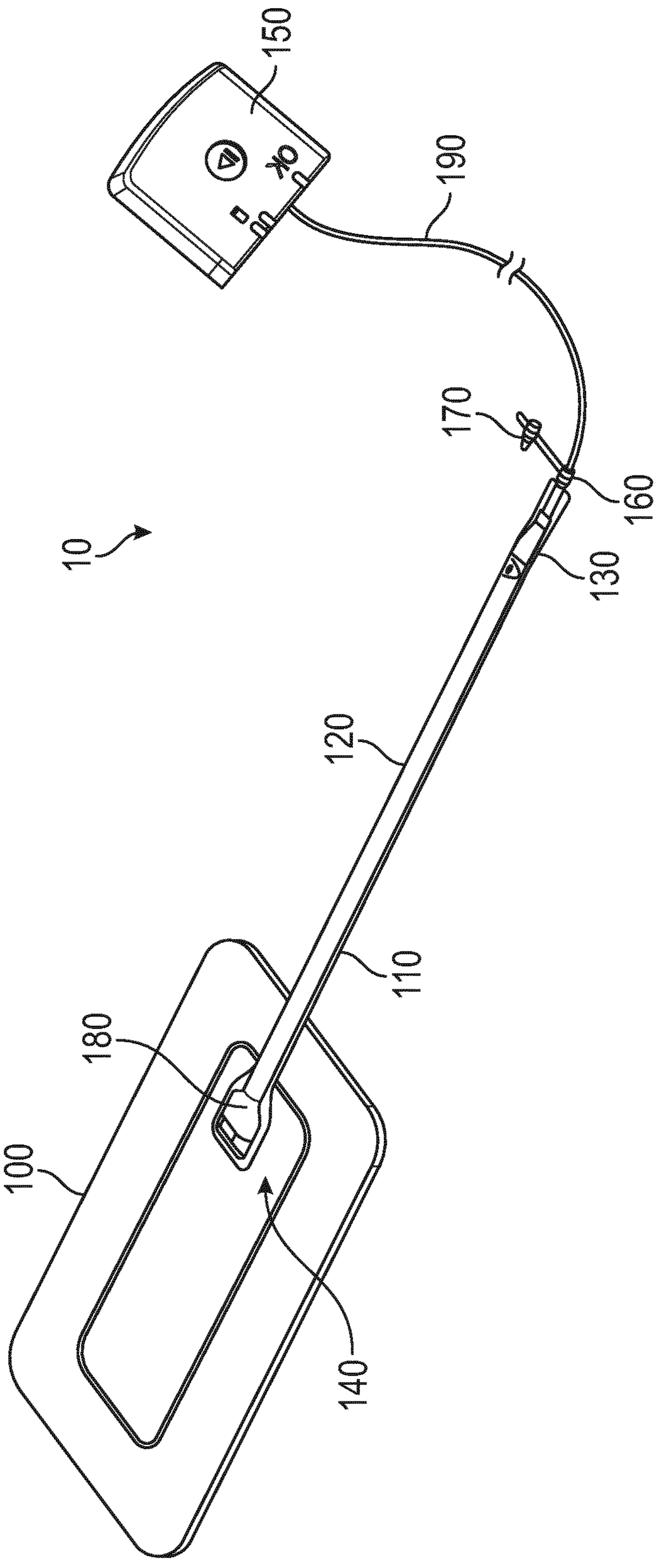


FIG. 1D

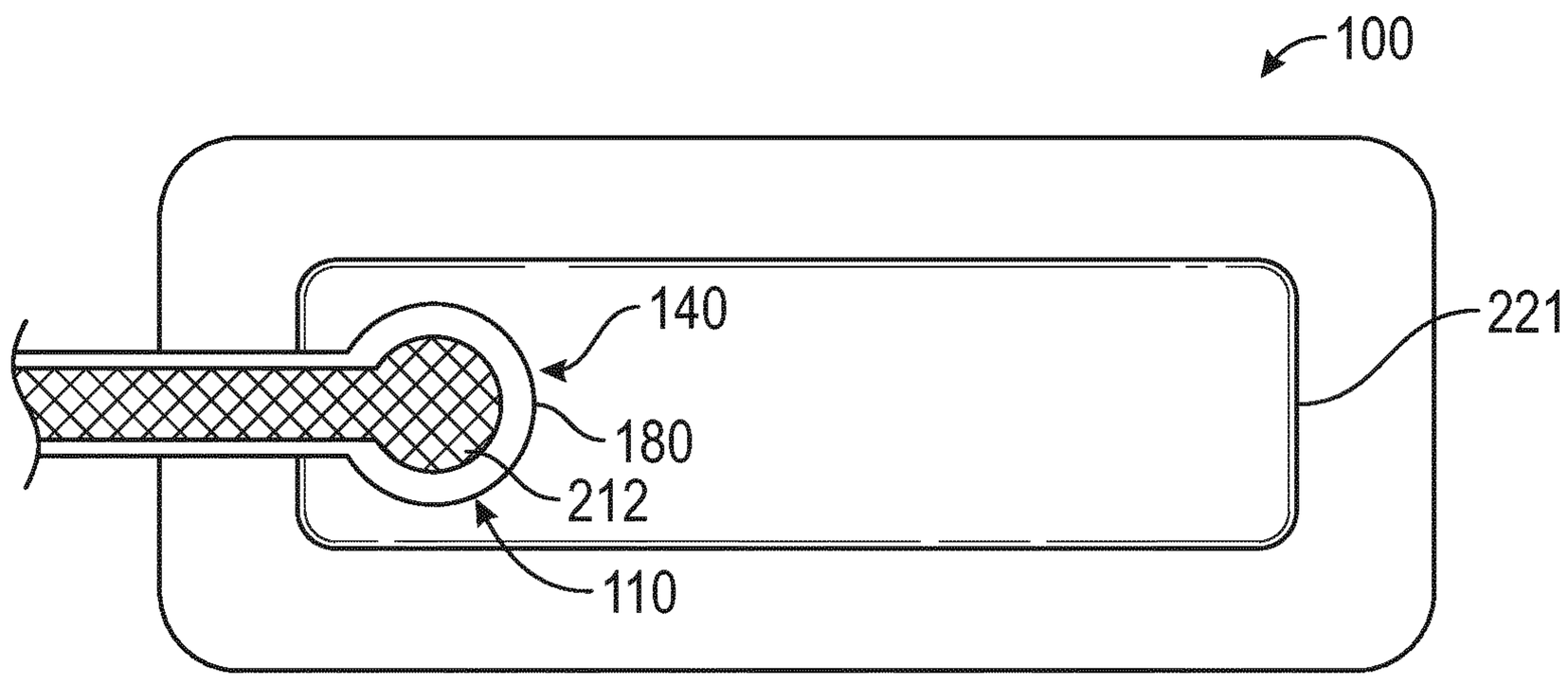


FIG. 1E

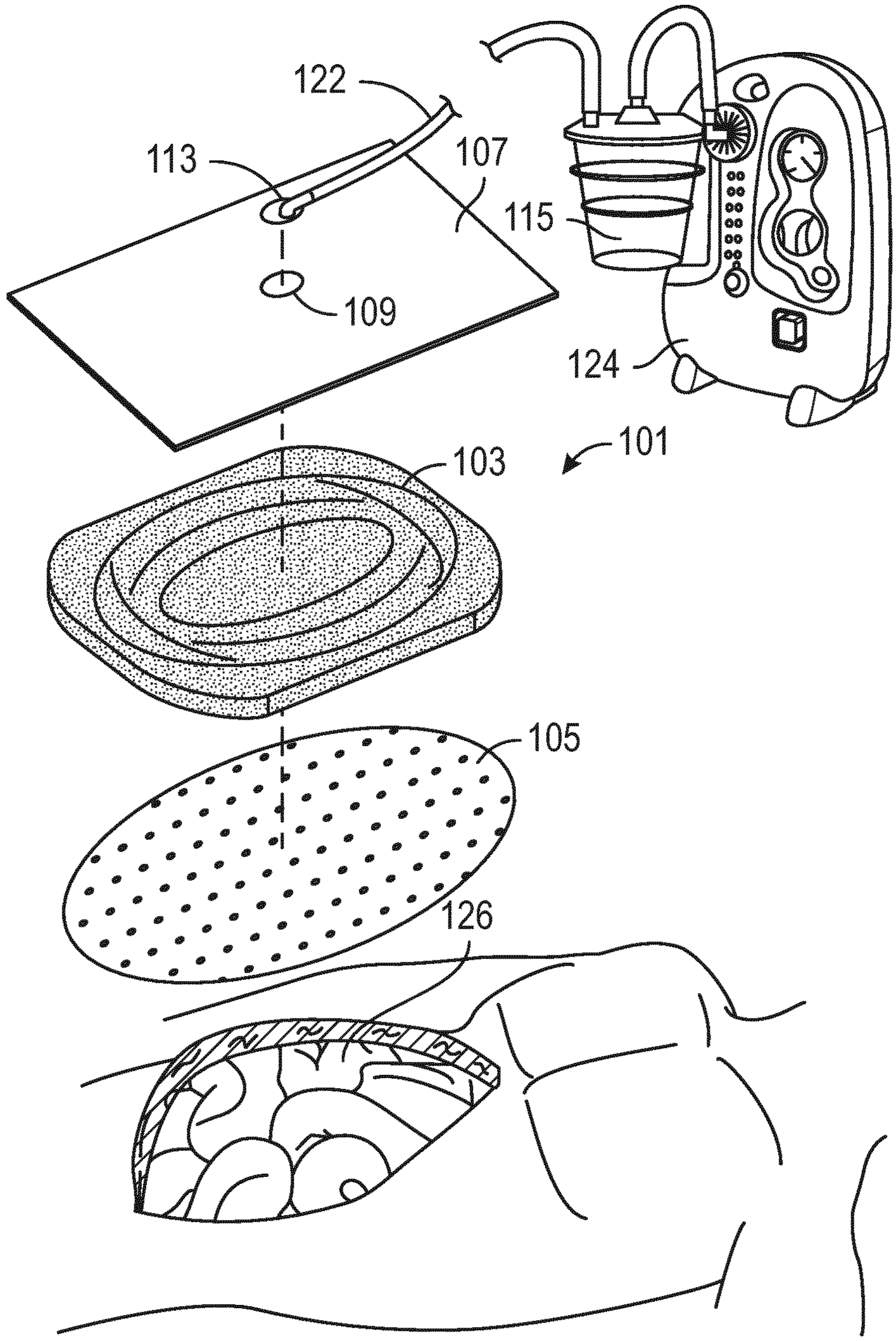


FIG. 1F

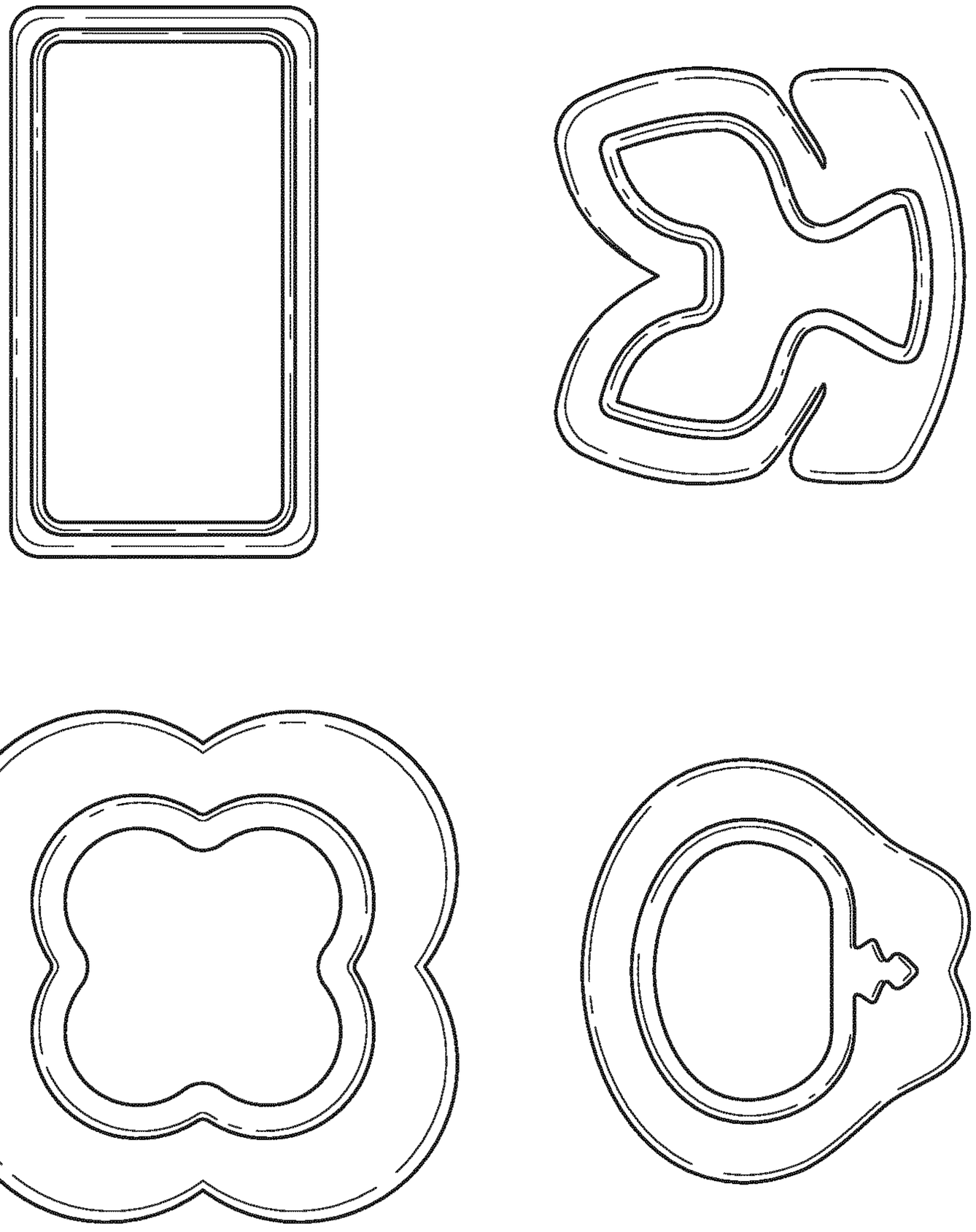


FIG. 1G

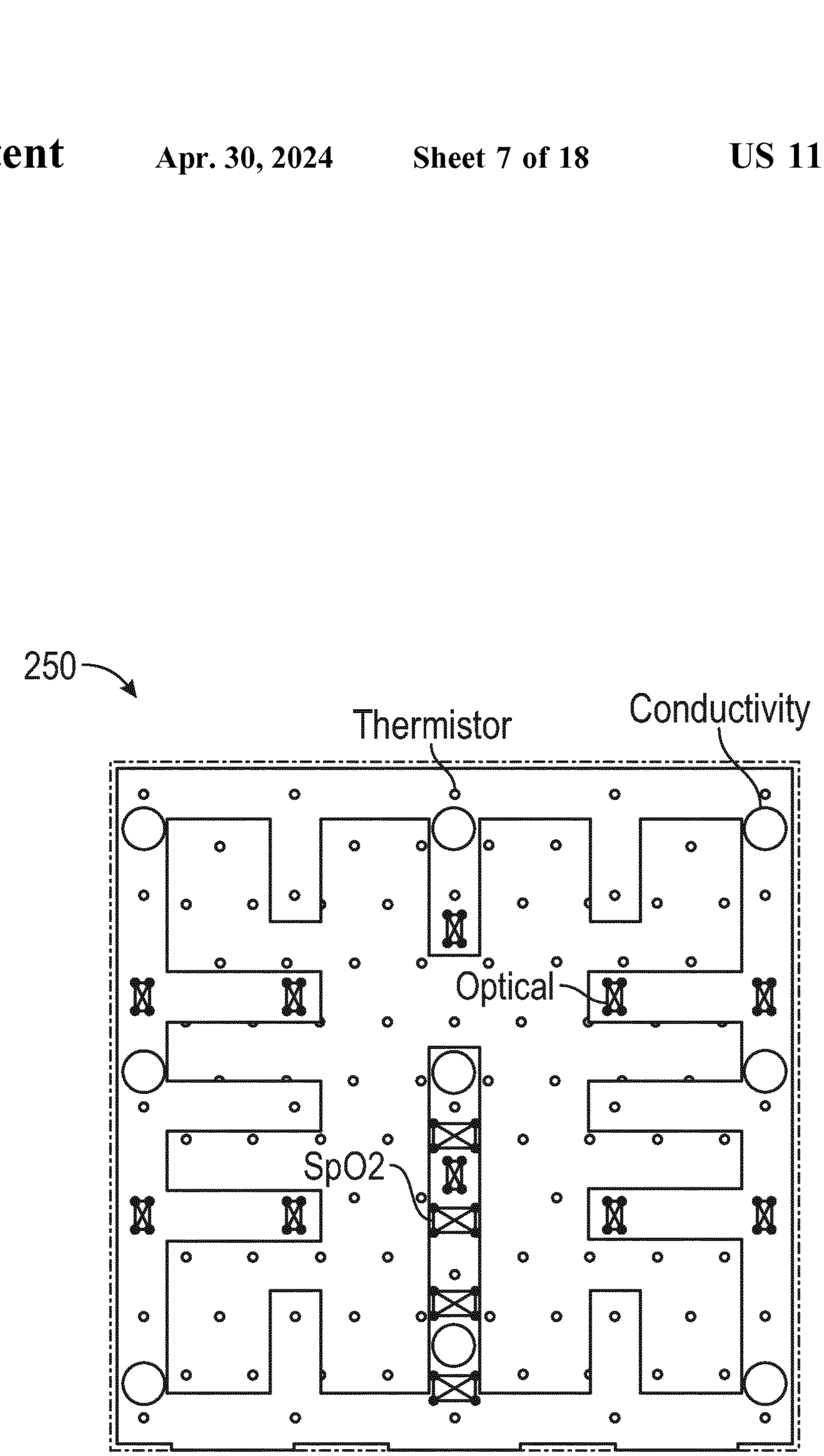


FIG. 2

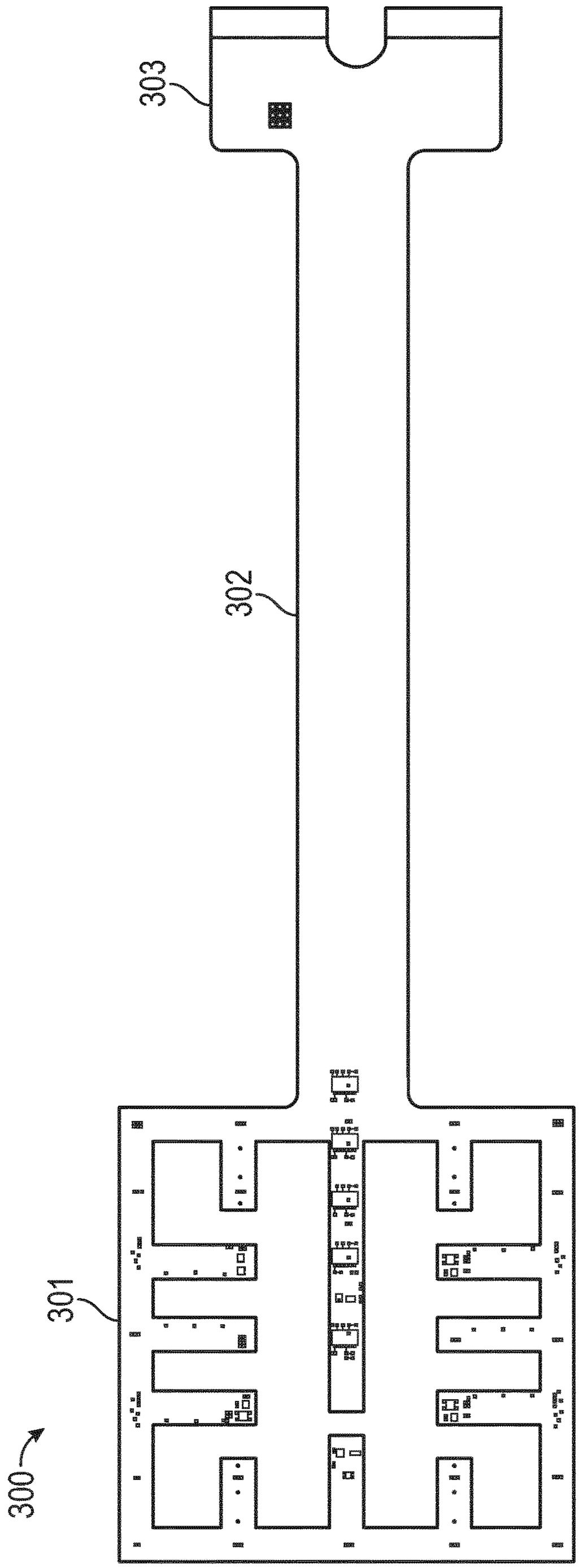


FIG. 3A

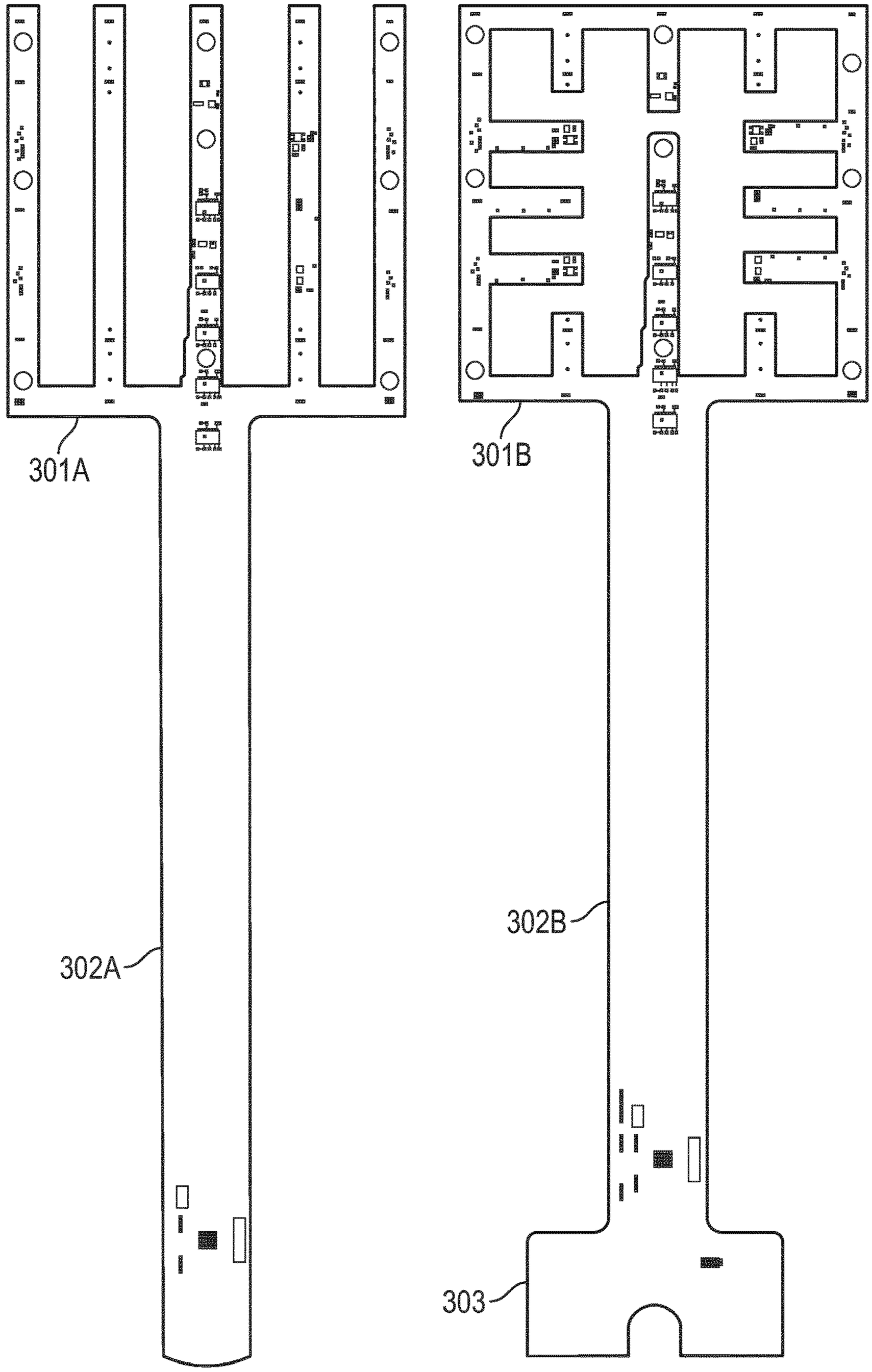


FIG. 3B

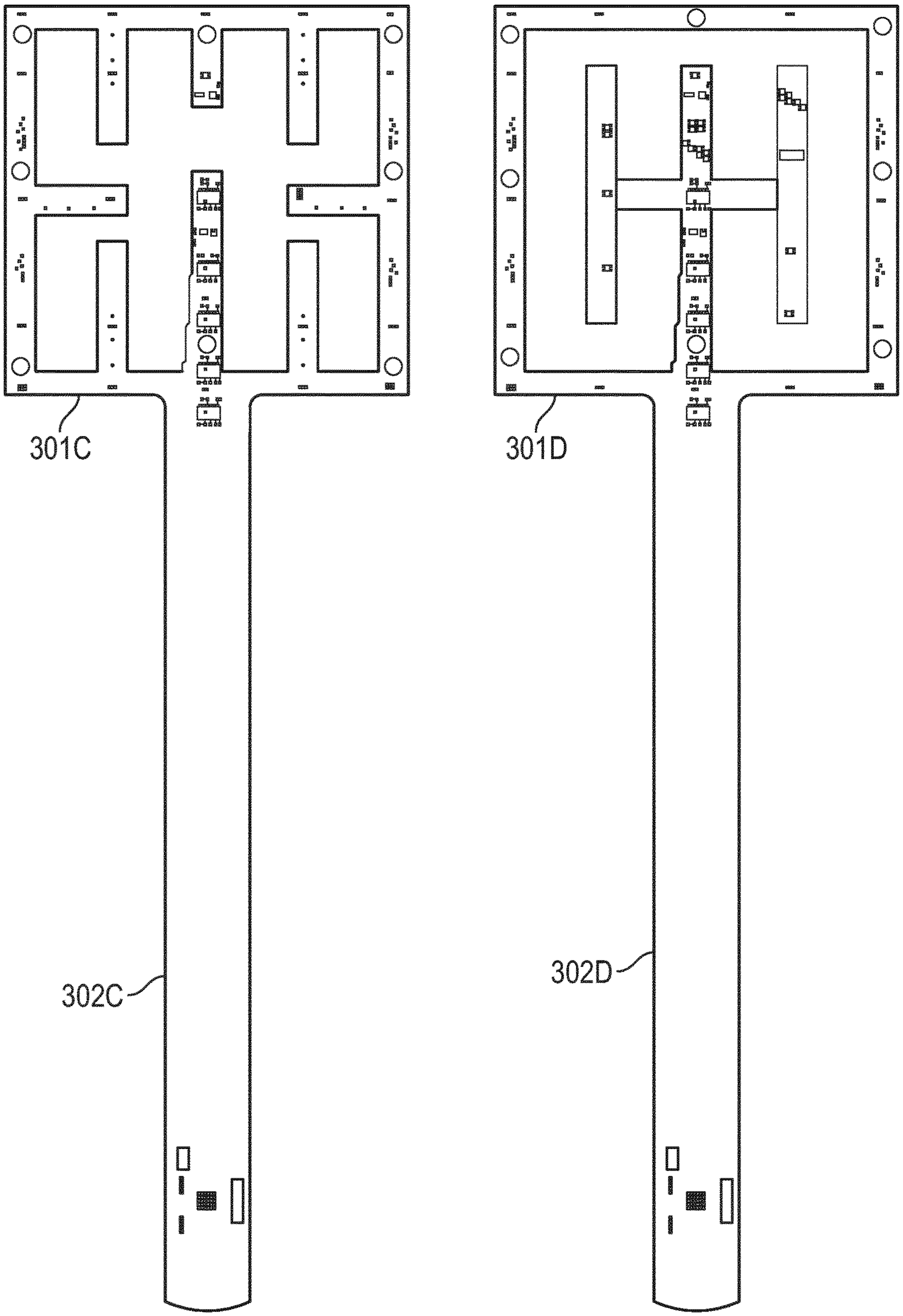


FIG. 3B
(Continued)

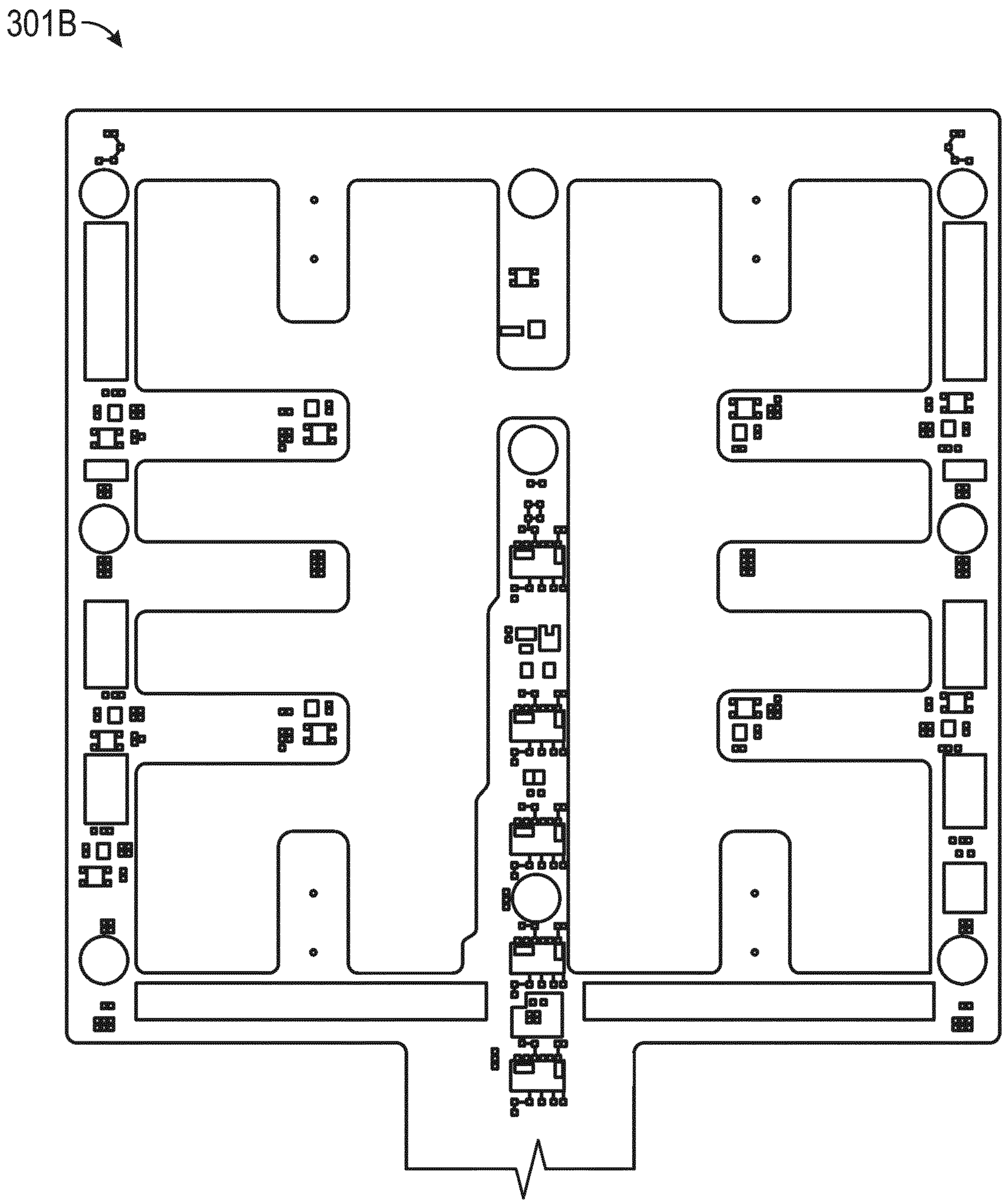


FIG. 3C

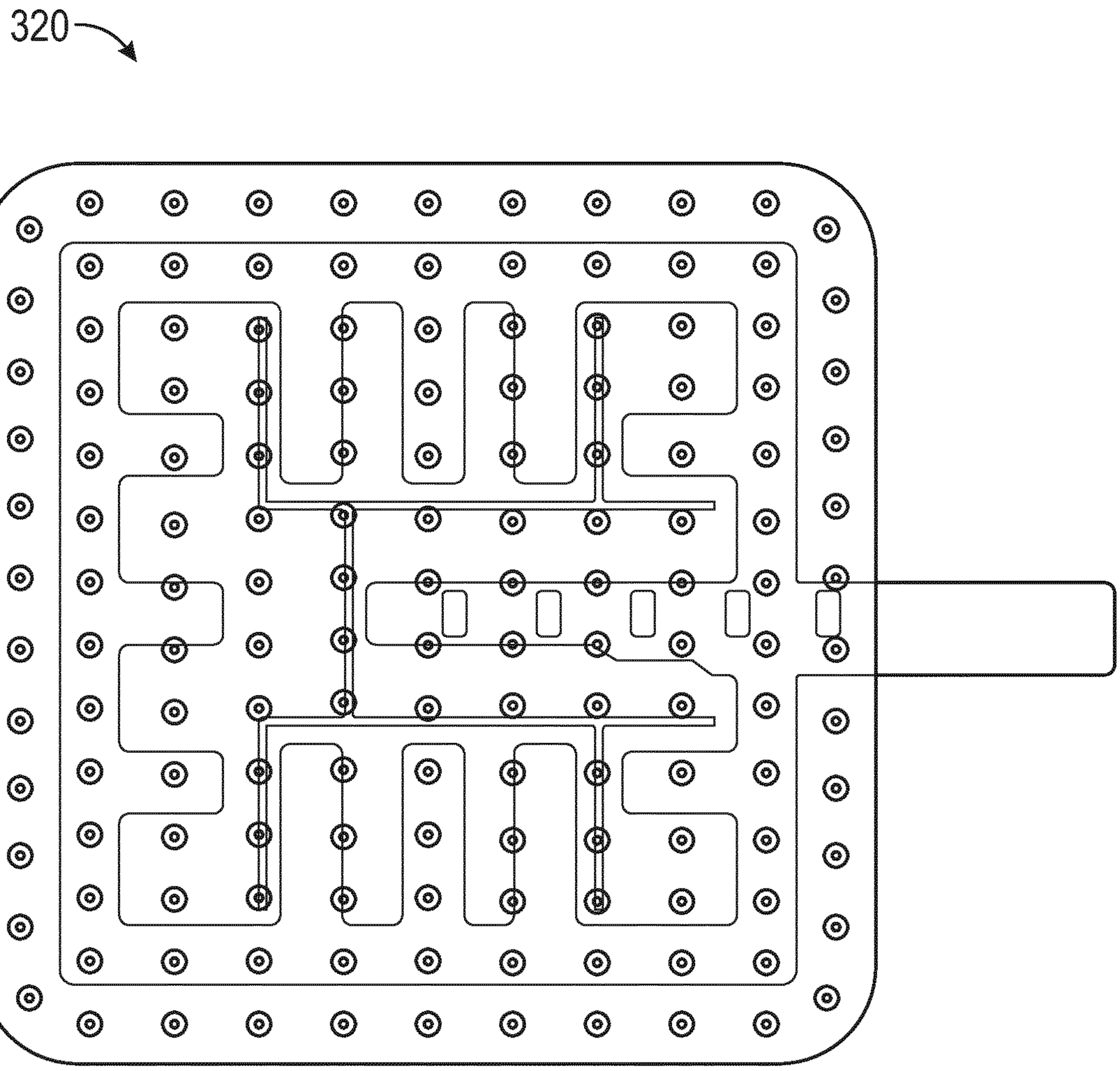


FIG. 3D

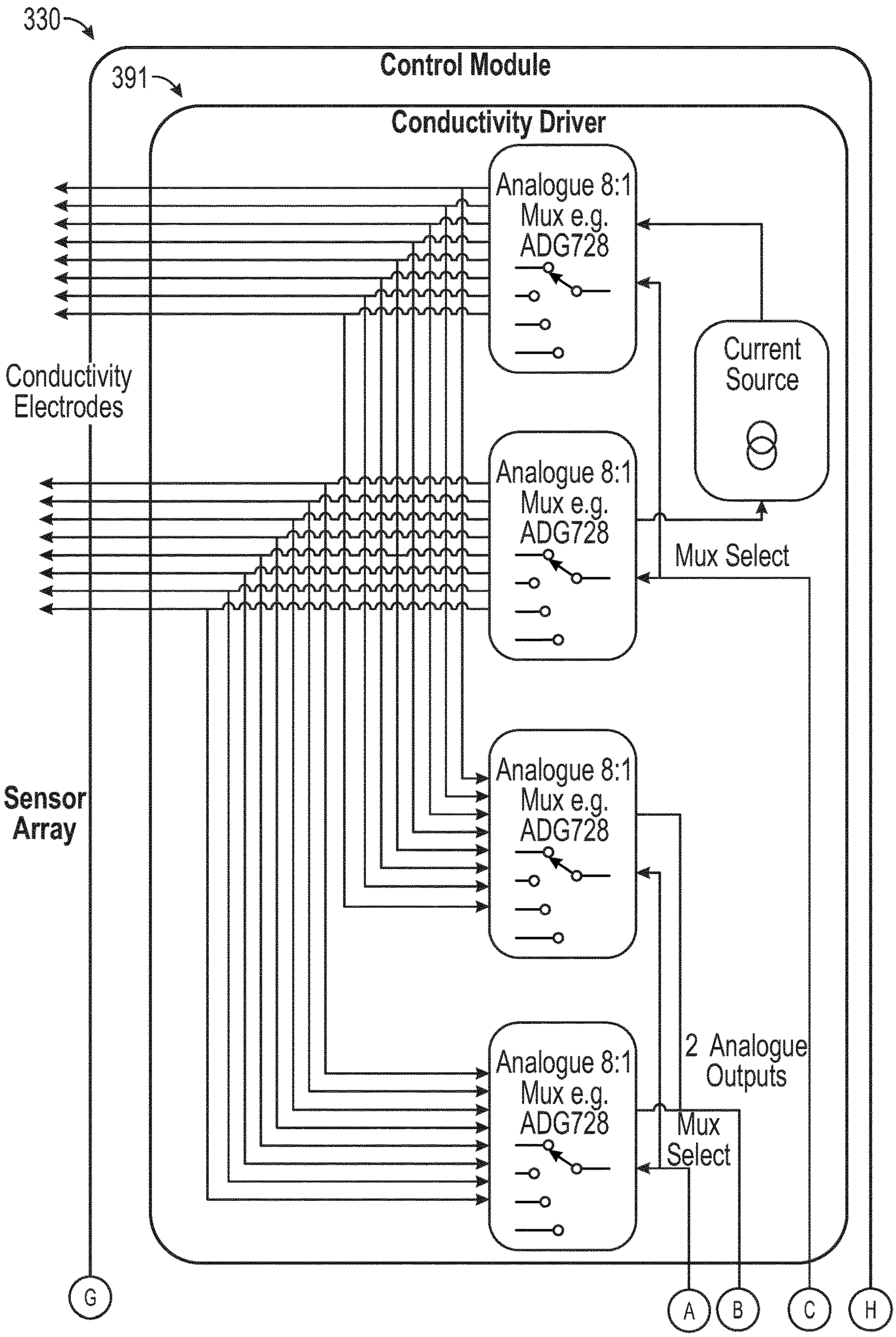

330
Control Module
391
Conductivity Driver
Analogue 8:1 Mux e.g. ADG728
Current Source
Conductivity Electrodes
Analogue 8:1 Mux e.g. ADG728
Mux Select
Sensor Array
Analogue 8:1 Mux e.g. ADG728
Analogue 8:1 Mux e.g. ADG728
2 Analogue Outputs
Mux Select
G
A
B
C
H

FIG. 3E

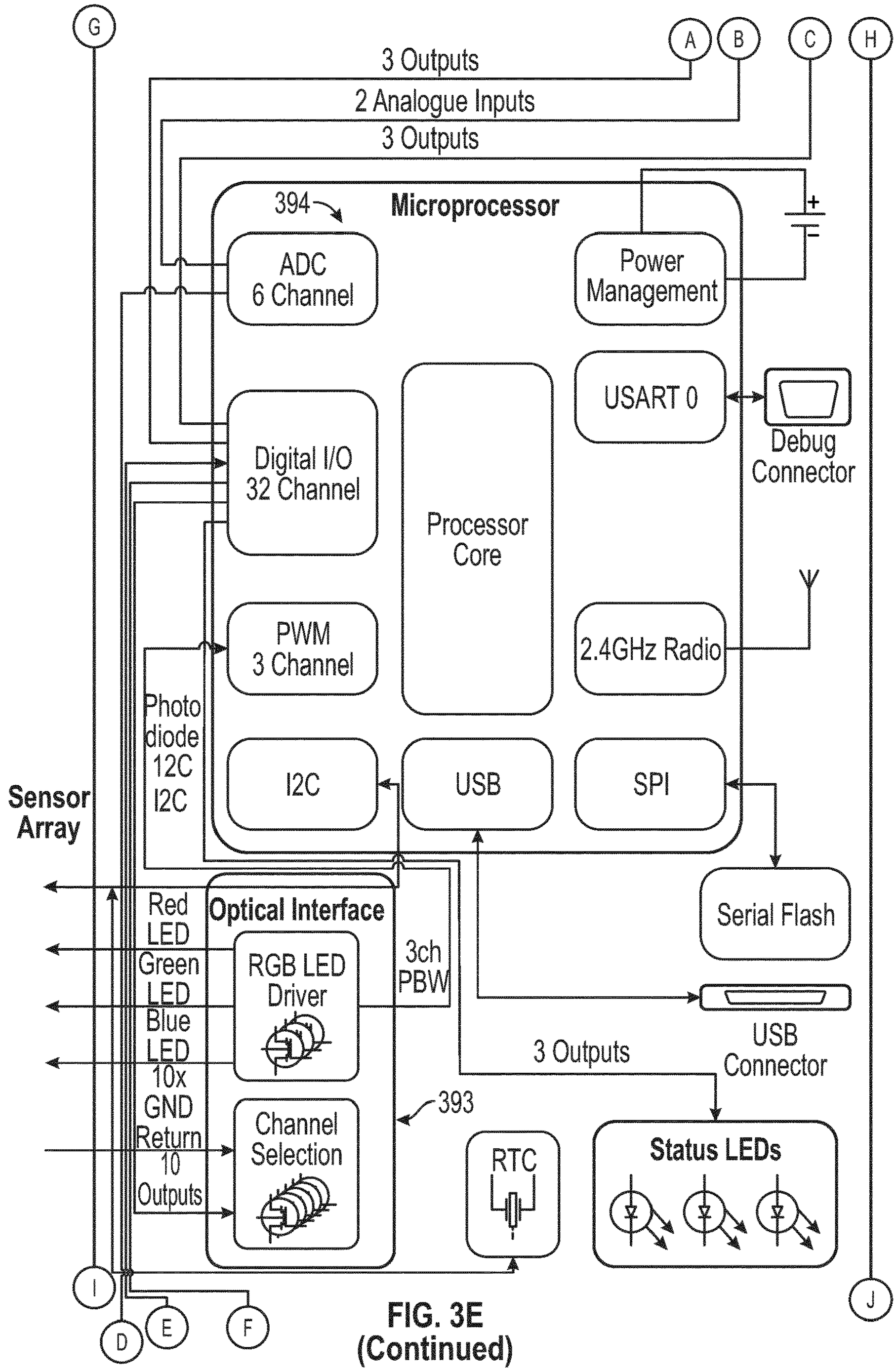


FIG. 3E
(Continued)

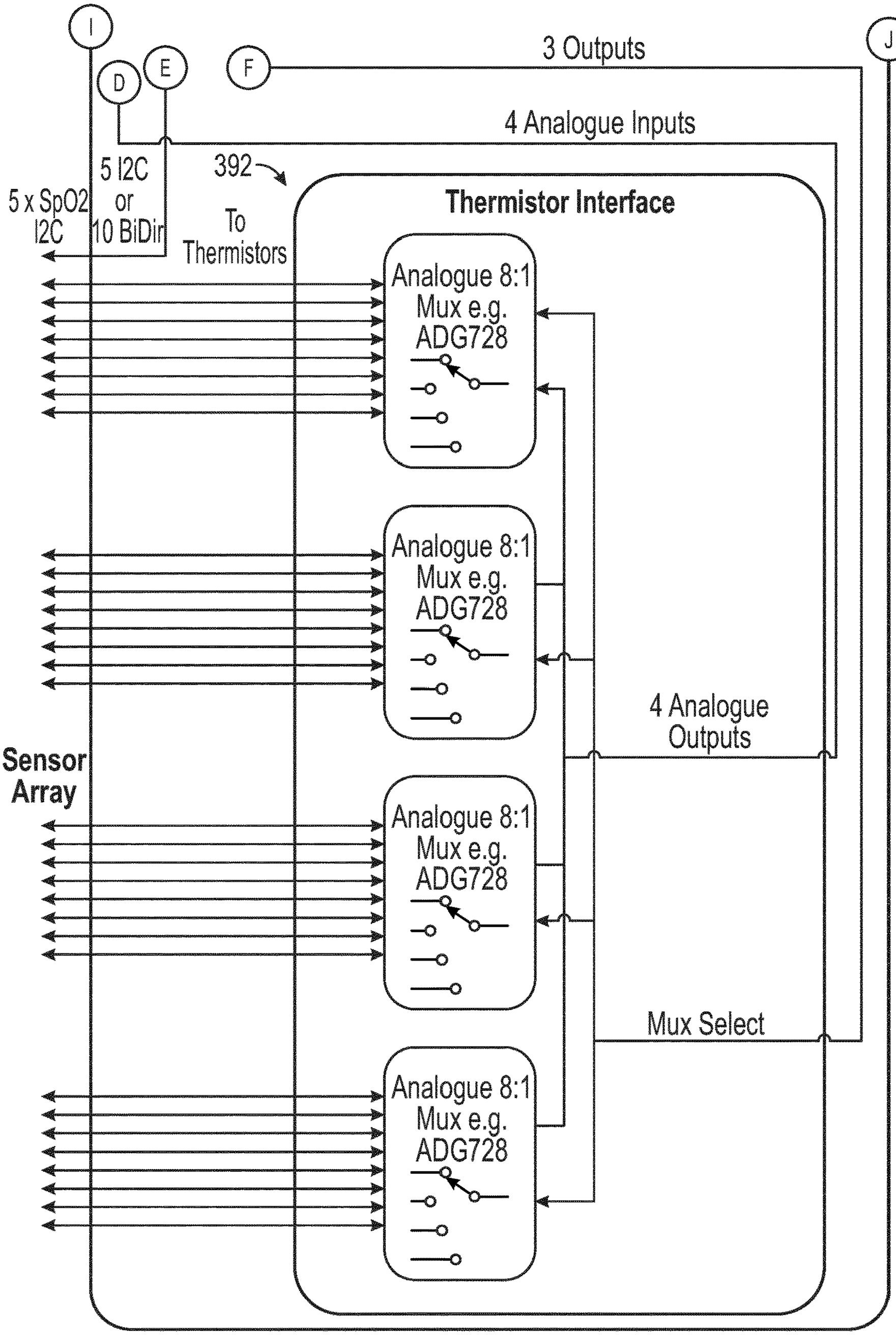


FIG. 3E
(Continued)

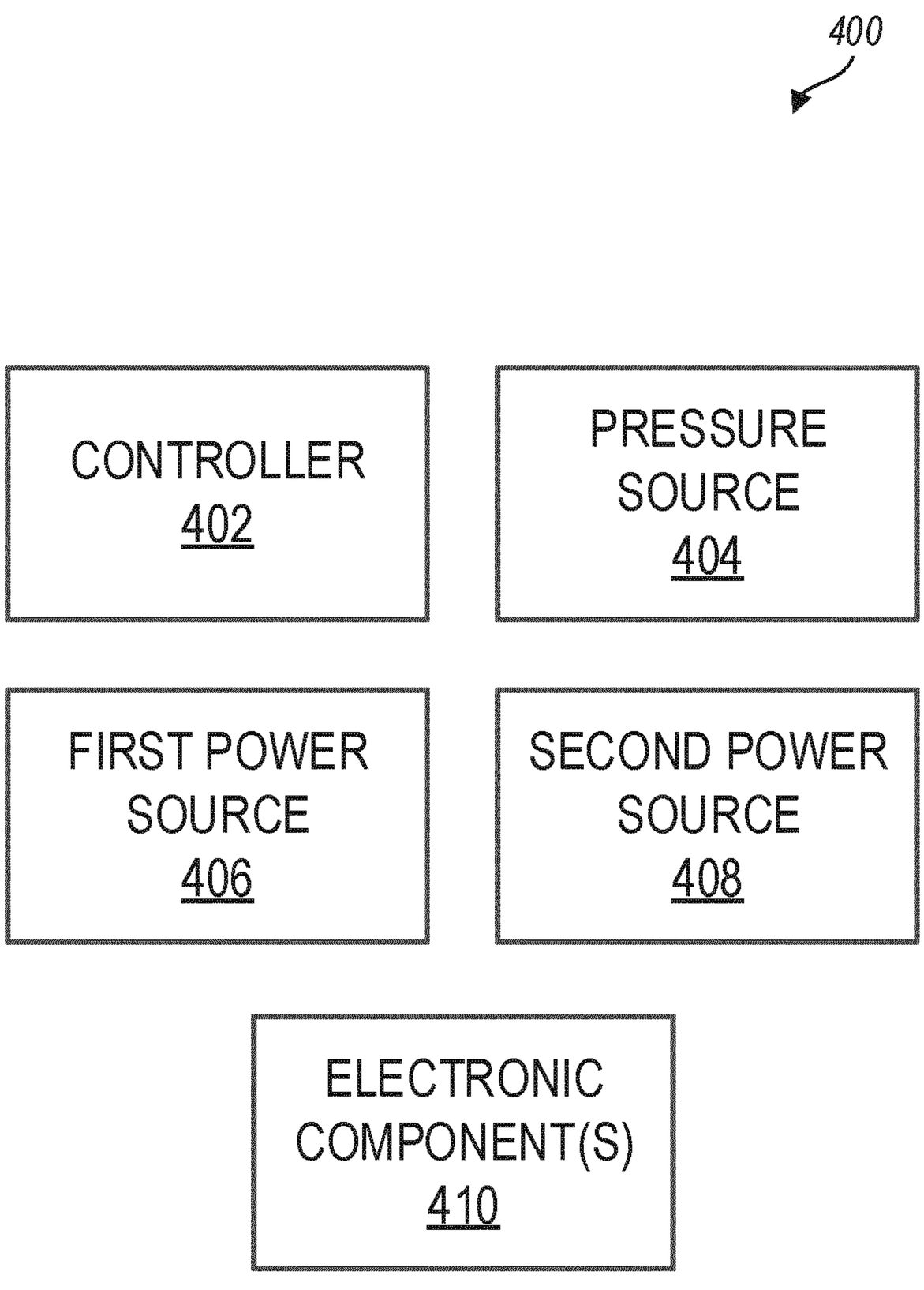

400
CONTROLLER
402
PRESSURE SOURCE
404
FIRST POWER SOURCE
406
SECOND POWER SOURCE
408
ELECTRONIC COMPONENT(S)
410

FIG. 4

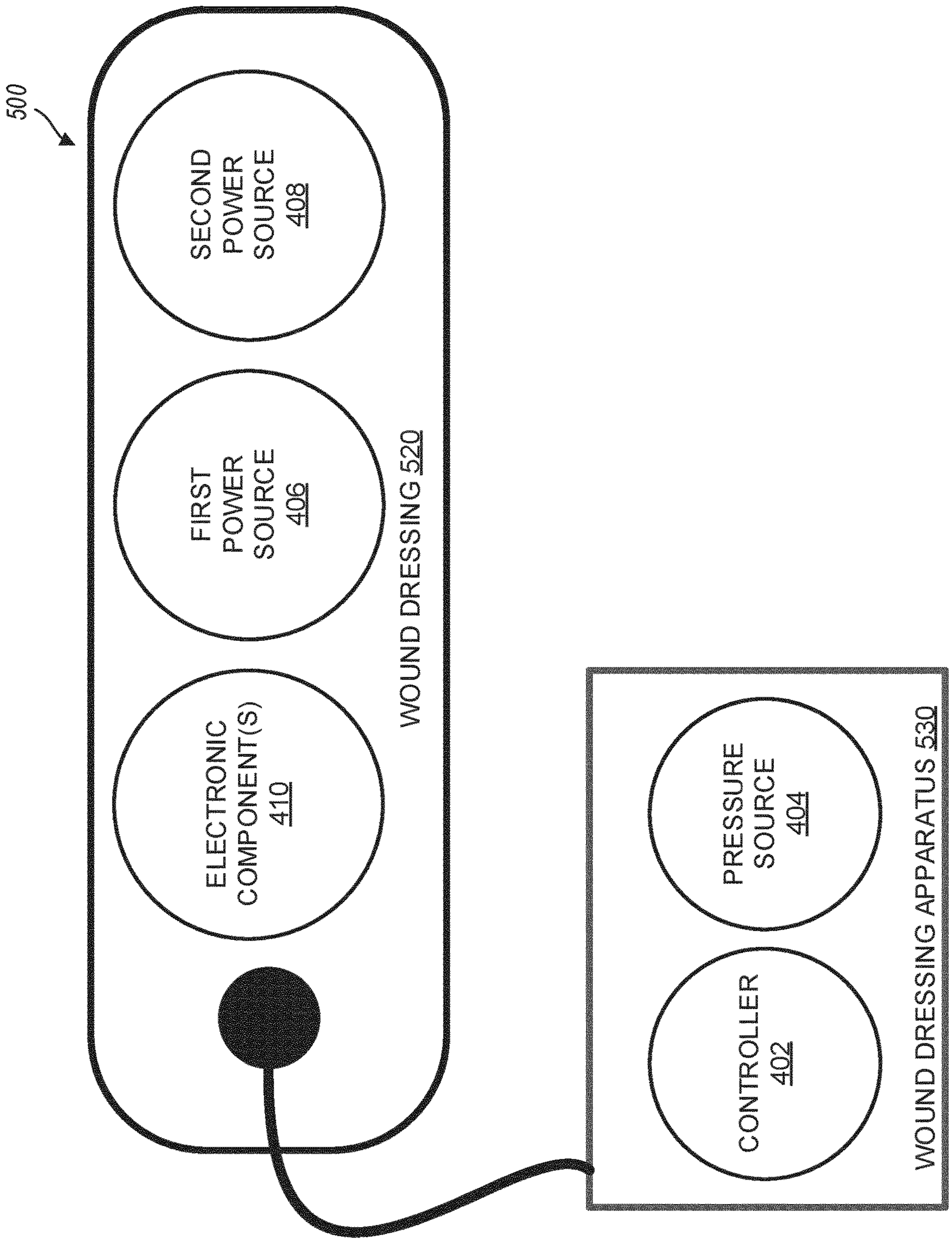

500
SECOND POWER SOURCE 408
FIRST POWER SOURCE 406
ELECTRONIC COMPONENT(S) 410
WOUND DRESSING 520
PRESSURE SOURCE 404
CONTROLLER 402
WOUND DRESSING APPARATUS 530

FIG. 5

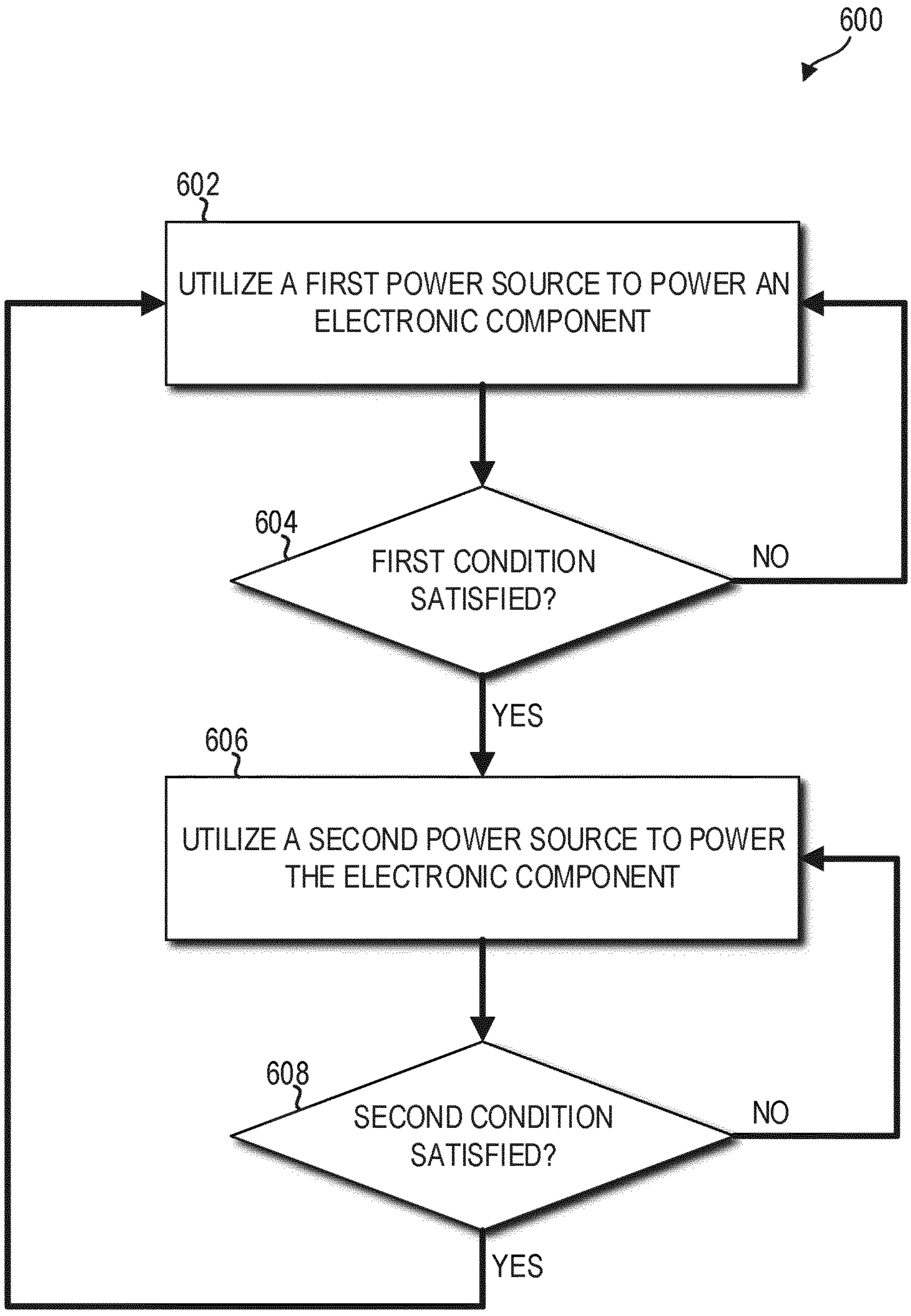

600
602
UTILIZE A FIRST POWER SOURCE TO POWER AN ELECTRONIC COMPONENT
604
FIRST CONDITION SATISFIED?
NO
YES
606
UTILIZE A SECOND POWER SOURCE TO POWER THE ELECTRONIC COMPONENT
608
SECOND CONDITION SATISFIED?
NO
YES

FIG. 6

WOUND THERAPY SYSTEMS AND METHODS WITH MULTIPLE POWER SOURCES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a U.S. national stage application of International Patent Application No. PCT/EP2019/085271, filed on Dec. 16, 2019, which claims priority to U.K. Provisional Application No. 1820927.0, filed on Dec. 21, 2018, entitled "WOUND THERAPY SYSTEMS AND METHODS WITH SUPERCAPACITORS", the disclosure of each of which is hereby incorporated by reference in its entirety.

FIELD

Embodiments of the present disclosure relate to apparatuses, systems, and methods for the treatment of tissues via sensor-enabled monitoring in communication with various therapy regimes.

BACKGROUND

Nearly all areas of medicine may benefit from improved information regarding the state of the tissue, organ, or system to be treated, particularly if such information is gathered in real-time during treatment. Many types of treatments are still routinely performed without the use of sensor data collection; instead, such treatments rely upon visual inspection by a caregiver or other limited means rather than quantitative sensor data. For example, in the case of wound treatment via dressings or negative pressure wound therapy, data collection is generally limited to visual inspection by a caregiver and often the underlying wounded tissue may be obscured by bandages or other visual impediments. Even intact, unwounded skin may have underlying damage that is not visible to the naked eye, such as a compromised vascular or deeper tissue damage that may lead to an ulcer. Similar to wound treatment, during orthopedic treatments requiring the immobilization of a limb with a cast or other encasement, only limited information is gathered on the underlying tissue. In instances of internal tissue repair, such as a bone plate, continued direct sensor-driven data collection is not performed. Further, braces or sleeves used to support musculoskeletal function do not monitor the functions of the underlying muscles or the movement of the limbs. Outside of direct treatments, common hospital room items such as beds and blankets could be improved by adding capability to monitor patient parameters.

Therefore, there is a need for improved sensor monitoring, particularly through the use of sensor-enabled substrates which can be incorporated into existing treatment regimes.

SUMMARY

Some embodiments of the present disclosure provide an improved system for providing therapy to a wound. A system for providing therapy to a wound can include a pressure source. The pressure source can be configured to provide negative pressure to a wound dressing positioned over a wound. The system can further include one or more controllers. The one or more controller can be configured to operate the pressure source and communicate with a first electronic component. The system can further include a first power source configured to power the first electronic component. The first power source can include a battery. The system can further include a second power source configured to power the first electronic component in place of the first power source. The second power source can include a capacitor.

The system of the preceding paragraph may also include any combination of the following features described in this paragraph, among other features described herein. The one or more controllers can be configured to, responsive to a first condition, cause the capacitor to power the first electronic component in place of the battery. The battery can be configured to power a second electronic component. The one or more controllers can be configured to, responsive to the first condition, cause the capacitor to power the first electronic component in place of the battery without causing the capacitor to power the second electronic component in place of the battery. The one or more controllers can be configured to, responsive to a second condition, cause the battery to power to the first electronic component in place of the capacitor. At least one of the first condition or the second condition can correspond to a capacity of the battery or the capacitor. The one or more controllers can be configured to determine an occurrence of the first condition or the second condition from a comparison of a value to a threshold, the value being indicative of a capacity of the battery or a capacity of the capacitor.

The system of any of the preceding paragraphs may also include any combination of the following features described in this paragraph, among other features described herein. At least one of the first electronic component or the second electronic component can include a clock or a wireless communications device. The first electronic component can include a sensor. The sensor can be configured to be positioned proximate the wound and provide measurement data to the one or more controllers. The measurement data can be usable by the one or more controllers to monitor healing of the wound.

The system of any of the preceding paragraphs may also include any combination of the following features described in this paragraph, among other features described herein. The first electronic component can include an electrical stimulator. The first electronic component can be supported by the wound dressing. The pressure source, the one or more controllers, the capacitor, and the battery are supported by the wound dressing. The capacitor can have a capacitance of between 100 mF to 100 F, 1 F to 10 F, or 2 F to 5 F. The one or more controllers can be a single controller. The capacitor can be configured to be charged by a power source other than the battery. The power source can be a coin cell. The battery can be configured to power the pressure source or the one or more controllers. A method of using the system of this paragraph or any of the preceding paragraphs can be provided.

Some embodiments of the present disclosure provide an improved wound monitoring or therapy apparatus. A wound monitoring or therapy apparatus can include a controller configured to communicate with a first electronic component. The wound monitoring or therapy apparatus can also include a first and second power source. The first power source can include a battery configured to power the first electronic component. The second power source can include a capacitor configured to power to the first electronic component in place of the battery.

The wound monitoring or therapy apparatus of the preceding paragraph may also include any combination of the following features described in this paragraph, among other features described herein. The controller can be configured

to, responsive to a first condition, cause the capacitor to power the first electronic component in place of the battery. The battery can be configured to power a second electronic component. The controller can be configured to, responsive to the first condition, cause the capacitor to power the first electronic component in place of the battery without causing the capacitor to power the second electronic component in place of the battery. The controller can be configured to, responsive to a second condition, cause the battery to power to the first electronic component in place of the capacitor. The first condition or the second condition can be indicative of a capacity of the battery or a capacity of the capacitor. The controller can be configured to determine an occurrence of the first condition or the second condition from a comparison of a value to a threshold. The value can be indicative of a capacity of the battery or a capacity of the capacitor.

The wound monitoring or therapy apparatus of any of the preceding paragraphs may also include any combination of the following features described in this paragraph, among other features described herein. The first electronic component can include a clock or a wireless communications device. The first electronic component can include a sensor. The sensor can be configured to be positioned proximate a wound and provide measurement data to the controller, the measurement data being usable by the controller to monitor healing of the wound. The first electronic component can include an electrical stimulator. The capacitor can have a capacitance value of between 100 mF to 100 F, 1 F to 10 F, or 2 F to 5 F. The controller can be a single controller. The controller can include a plurality of controllers. The capacitor can be configured to be charged by a power source other than the battery.

The wound monitoring or therapy apparatus of any of the preceding paragraphs may also include any combination of the following features described in this paragraph, among other features described herein. The capacitor can be configured to be charged by a coin cell. The capacitor can be configured to be charged by the battery. The battery can be configured to power the pressure source or the controller. The capacitor can be configured to power the pressure source or the controller. The wound monitoring or therapy apparatus can further include a wound dressing configured to be positioned in contact with a wound. The first electronic component can be supported by the wound dressing. The battery or the capacitor can be supported by the wound dressing. The controller can be supported by the wound dressing. The system can further include a negative pressure source configured to provide negative pressure to the wound dressing. A method of using the wound monitoring or therapy apparatus of this paragraph or any of the preceding paragraphs can be provided.

Any of the features, components, or details of any of the arrangements or embodiments disclosed in this application, including without limitation any of the pump embodiments, any of the negative pressure wound therapy embodiments, any of the wound dressing embodiments, or any of the optical sensor embodiments disclosed below, are interchangeably combinable with any other features, components, or details of any of the arrangements or embodiments disclosed herein to form new arrangements and embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure will now be described hereinafter, by way of example only, with reference to the accompanying drawings in which:

FIG. **1**A illustrates an example negative pressure wound treatment system;

FIG. **1**B illustrates an example wound dressing;

FIG. **1**C illustrates an example negative pressure wound treatment system employing a flexible fluidic connector and a wound dressing capable of absorbing and storing wound exudate;

FIG. **1**D illustrates an example negative pressure wound treatment system employing a flexible fluidic connector and a wound dressing capable of absorbing and storing wound exudate;

FIG. **1**E illustrates an example negative pressure wound treatment system employing a flexible fluidic connector and a wound dressing capable of absorbing and storing wound exudate;

FIG. **1**F illustrates of an example negative pressure wound treatment system;

FIG. **1**G illustrates an example wound treatment system employing a wound dressing capable of absorbing and storing wound exudate to be used without negative pressure;

FIG. **2** illustrates an example sensor array illustrating the sensor placement incorporated into a wound dressing;

FIG. **3**A illustrates an example flexible sensor array including a sensor array portion, a tail portion, and a connector pad end portion;

FIG. **3**B illustrates example flexible circuit boards with different sensor array geometries;

FIG. **3**C illustrates the sensor array portion of the sensor array shown in FIG. **3**B;

FIG. **3**D illustrates an example flexible sensor array incorporated into a perforated wound contact layer;

FIG. **3**E illustrates an example control module;

FIG. **4** illustrates an example wound treatment system;

FIG. **5** illustrates an example configuration of the wound treatment system of FIG. **4**; and

FIG. **6** is a flow diagram illustrative of an example routine for monitoring or providing therapy to a wound.

DETAILED DESCRIPTION

Examples disclosed herein relate to apparatuses and methods of monitoring and treating biological tissue with sensor-enabled substrates. The examples disclosed herein are not limited to treatment or monitoring of a particular type of tissue or injury, instead the sensor-enabled technologies disclosed herein are broadly applicable to any type of therapy that may benefit from sensor-enabled substrates. Some implementations utilize sensors and data collection relied upon by health care providers to make both diagnostic and patient management decisions.

Some examples disclosed herein relate to the use of sensors mounted on or embedded within substrates configured to be used in the treatment of both intact and damaged human or animal tissue. Such sensors may collect information about the surrounding tissue and transmit such information to a computing device or a caregiver to be utilized in further treatment. In certain examples, such sensors may be attached to the skin anywhere on the body, including areas for monitoring arthritis, temperature, or other areas that may be prone to problems and require monitoring. Sensors disclosed herein may also incorporate markers, such as radiopaque markers, to indicate the presence of the device, for example prior to performing an MRI or other technique.

The sensor examples disclosed herein may be used in combination with clothing. Non-limiting examples of clothing for use with the sensors disclosed herein include shirts, pants, trousers, dresses, undergarments, outer-garments,

gloves, shoes, hats, and other suitable garments. In certain examples, the sensor examples disclosed herein may be welded into or laminated into/onto the particular garments. The sensor examples may be printed directly onto the garment or embedded into the fabric. Breathable and printable materials such as microporous membranes may also be suitable.

Sensor examples disclosed herein may be incorporated into cushioning or bed padding, such as within a hospital bed, to monitor patient characteristics, such as any characteristic disclosed herein. In certain examples, a disposable film containing such sensors could be placed over the hospital bedding and removed/replaced as needed.

In some implementations, the sensor examples disclosed herein may incorporate energy harvesting, such that the sensor examples are self-sustaining. For example, energy may be harvested from thermal energy sources, kinetic energy sources, chemical gradients, or any suitable energy source.

The sensor examples disclosed herein may be utilized in rehabilitation devices and treatments, including sports medicine. For example, the sensor examples disclosed herein may be used in braces, sleeves, wraps, supports, and other suitable items. Similarly, the sensor examples disclosed herein may be incorporated into sporting equipment, such as helmets, sleeves, or pads. For example, such sensor examples may be incorporated into a protective helmet to monitor characteristics such as acceleration, which may be useful in concussion diagnosis.

The sensor examples disclosed herein may be used in coordination with surgical devices, for example, the NAVIO surgical system by Smith & Nephew Inc. In implementations, the sensor examples disclosed herein may be in communication with such surgical devices to guide placement of the surgical devices. In some implementations, the sensor examples disclosed herein may monitor blood flow to or away from the potential surgical site or ensure that there is no blood flow to a surgical site. Further surgical data may be collected to aid in the prevention of scarring and monitor areas away from the impacted area.

To further aid in surgical techniques, the sensors disclosed herein may be incorporated into a surgical drape to provide information regarding tissue under the drape that may not be immediately visible to the naked eye. For example, a sensor embedded flexible drape may have sensors positioned advantageously to provide improved area-focused data collection. In certain implementations, the sensor examples disclosed herein may be incorporated into the border or interior of a drape to create fencing to limit/control the surgical theater.

Sensor examples as disclosed herein may also be utilized for pre-surgical assessment. For example, such sensor examples may be used to collect information about a potential surgical site, such as by monitoring skin and the underlying tissues for a possible incision site. For example, perfusion levels or other suitable characteristics may be monitored at the surface of the skin and deeper in the tissue to assess whether an individual patient may be at risk for surgical complications. Sensor examples such as those disclosed herein may be used to evaluate the presence of microbial infection and provide an indication for the use of antimicrobials. Further, sensor examples disclosed herein may collect further information in deeper tissue, such as identifying pressure ulcer damage or the fatty tissue levels.

The sensor examples disclosed herein may be utilized in cardiovascular monitoring. For example, such sensor examples may be incorporated into a flexible cardiovascular monitor that may be placed against the skin to monitor characteristics of the cardiovascular system and communicate such information to another device or a caregiver. For example, such a device may monitor pulse rate, oxygenation of the blood, or electrical activity of the heart. Similarly, the sensor examples disclosed herein may be utilized for neurophysiological applications, such as monitoring electrical activity of neurons.

The sensor examples disclosed herein may be incorporated into implantable devices, such as implantable orthopedic implants, including flexible implants. Such sensor examples may be configured to collect information regarding the implant site and transmit this information to an external source. In some cases, an internal source may also provide power for such an implant.

The sensor examples disclosed herein may also be utilized for monitoring biochemical activity on the surface of the skin or below the surface of the skin, such as lactose buildup in muscle or sweat production on the surface of the skin. In some cases, other characteristics may be monitored, such as glucose concentration, urine concentration, tissue pressure, skin temperature, skin surface conductivity, skin surface resistivity, skin hydration, skin maceration, or skin ripping.

Sensor examples as disclosed herein may be incorporated into Ear, Nose, and Throat (ENT) applications. For example, such sensor examples may be utilized to monitor recovery from ENT-related surgery, such as wound monitoring within the sinus passage.

As described in greater detail below, the sensor examples disclosed herein may encompass sensor printing technology with encapsulation, such as encapsulation with a polymer film. Such a film may be constructed using any polymer described herein, such as polyurethane. Encapsulation of the sensor examples may provide waterproofing of the electronics and protection from local tissue, local fluids, and other sources of potential damage.

In certain examples, the sensors disclosed herein may be incorporated into an organ protection layer such as disclosed below. Such a sensor-embedded organ protection layer may both protect the organ of interest and confirm that the organ protection layer is in position and providing protection. Further, a sensor-embedded organ protection layer may be utilized to monitor the underlying organ, such as by monitoring blood flow, oxygenation, and other suitable markers of organ health. In some cases, a sensor-enabled organ protection layer may be used to monitor a transplanted organ, such as by monitoring the fat and muscle content of the organ. Further, sensor-enabled organ protection layers may be used to monitor an organ during and after transplant, such as during rehabilitation of the organ.

The sensor examples disclosed herein may be incorporated into treatments for wounds (disclosed in greater detail below) or in a variety of other applications. Non-limiting examples of additional applications for the sensor examples disclosed herein include: monitoring and treatment of intact skin, cardiovascular applications such as monitoring blood flow, orthopedic applications such as monitoring limb movement and bone repair, neurophysiological applications such as monitoring electrical impulses, and any other tissue, organ, system, or condition that may benefit from improved sensor-enabled monitoring.

Wound Therapy

Some examples disclosed herein relate to wound therapy for a human or animal body. Therefore, any reference to a wound herein can refer to a wound on a human or animal body, and any reference to a body herein can refer to a human or animal body. The disclosed technology examples

may relate to preventing or minimizing damage to physiological tissue or living tissue, or to the treatment of damaged tissue (for example, a wound as described herein) wound with or without reduced pressure, including for example a source of negative pressure and wound dressing components and apparatuses. The apparatuses and components comprising the wound overlay and packing materials or internal layers, if any, are sometimes collectively referred to herein as dressings. In some cases, the wound dressing can be provided to be utilized without reduced pressure.

Some examples disclosed herein relate to wound therapy for a human or animal body. Therefore, any reference to a wound herein can refer to a wound on a human or animal body, and any reference to a body herein can refer to a human or animal body. The disclosed technology examples may relate to preventing or minimizing damage to physiological tissue or living tissue, or to the treatment of damaged tissue (for example, a wound as described herein).

As used herein the expression "wound" may include an injury to living tissue may be caused by a cut, blow, or other impact, typically one in which the skin is cut or broken. A wound may be a chronic or acute injury. Acute wounds occur as a result of surgery or trauma. They move through the stages of healing within a predicted timeframe. Chronic wounds typically begin as acute wounds. The acute wound can become a chronic wound when it does not follow the healing stages resulting in a lengthened recovery. It is believed that the transition from acute to chronic wound can be due to a patient being immuno-compromised.

Chronic wounds may include for example: venous ulcers (such as those that occur in the legs), which account for the majority of chronic wounds and mostly affect the elderly, diabetic ulcers (for example, foot or ankle ulcers), peripheral arterial disease, pressure ulcers, or epidermolysis bullosa (EB).

Examples of other wounds include, but are not limited to, abdominal wounds or other large or incisional wounds, either as a result of surgery, trauma, sterniotomies, fasciotomies, or other conditions, dehisced wounds, acute wounds, chronic wounds, subacute and dehisced wounds, traumatic wounds, flaps and skin grafts, lacerations, abrasions, contusions, burns, diabetic ulcers, pressure ulcers, stoma, surgical wounds, trauma and venous ulcers or the like.

Wounds may also include a deep tissue injury. Deep tissue injury is a term proposed by the National Pressure Ulcer Advisory Panel (NPUAP) to describe a unique form of pressure ulcers. These ulcers have been described by clinicians for many years with terms such as purple pressure ulcers, ulcers that are likely to deteriorate and bruises on bony prominences.

Wound may also include tissue at risk of becoming a wound as discussed herein. For example, tissue at risk may include tissue over a bony protuberance (at risk of deep tissue injury/insult) or pre-surgical tissue (for example, knee tissue) that may has the potential to be cut (for example, for joint replacement/surgical alteration/reconstruction).

Some examples relate to methods of treating a wound with the technology disclosed herein in conjunction with one or more of the following: advanced footwear, turning a patient, offloading (such as, offloading diabetic foot ulcers), treatment of infection, systemix, antimicrobial, antibiotics, surgery, removal of tissue, affecting blood flow, physiotherapy, exercise, bathing, nutrition, hydration, nerve stimulation, ultrasound, electrostimulation, oxygen therapy, microwave therapy, active agents ozone, antibiotics, antimicrobials, or the like.

Alternatively or additionally, a wound may be treated using topical negative pressure or traditional advanced wound care, which is not aided by the using of applied negative pressure (may also be referred to as non-negative pressure therapy).

Advanced wound care may include use of an absorbent dressing, an occlusive dressing, use of an antimicrobial or debriding agents in a wound dressing or adjunct, a pad (for example, a cushioning or compressive therapy, such as stockings or bandages), or the like.

In some cases, treatment of such wounds can be performed using traditional wound care, wherein a dressing can be applied to the wound to facilitate and promote healing of the wound.

Some examples relate to methods of manufacturing a wound dressing comprising providing a wound dressing as disclosed herein.

Negative Pressure Wound Dressing

In some cases, treatment of such wounds can be performed using negative pressure wound therapy, wherein a reduced or negative pressure can be applied to the wound to facilitate and promote healing of the wound. It will also be appreciated that the wound dressing and methods as disclosed herein may be applied to other parts of the body, and are not necessarily limited to treatment of wounds.

It will be understood that examples of the present disclosure are generally applicable to use in topical negative pressure ("TNP") therapy systems. Briefly, negative pressure wound therapy assists in the closure and healing of many forms of "hard to heal" wounds by reducing tissue oedema; encouraging blood flow and granular tissue formation; removing excess exudate and may reduce bacterial load (and thus infection risk). In addition, the therapy allows for less disturbance of a wound leading to more rapid healing. TNP therapy systems may also assist on the healing of surgically closed wounds by removing fluid and by helping to stabilize the tissue in the apposed position of closure. A further beneficial use of TNP therapy can be found in grafts and flaps where removal of excess fluid is important and close proximity of the graft to tissue is required in order to ensure tissue viability.

Negative pressure therapy can be used for the treatment of open or chronic wounds that are too large to spontaneously close or otherwise fail to heal by means of applying negative pressure to the site of the wound. Topical negative pressure (TNP) therapy or negative pressure wound therapy (NPWT) involves placing a cover that is impermeable or semi-permeable to fluids over the wound, using various means to seal the cover to the tissue of the patient surrounding the wound, and connecting a source of negative pressure (such as a vacuum pump) to the cover in a manner so that negative pressure is created and maintained under the cover. It is believed that such negative pressures promote wound healing by facilitating the formation of granulation tissue at the wound site and assisting the body's normal inflammatory process while simultaneously removing excess fluid, which may contain adverse cytokines or bacteria.

Some of the dressings used in NPWT can include many different types of materials and layers, for example, gauze, pads, foam pads or multi-layer wound dressings. One example of a multi-layer wound dressing is the PICO dressing, available from Smith & Nephew, includes a wound contact layer and a superabsorbent layer beneath a backing layer to provide a canister-less system for treating a wound with NPWT. The wound dressing may be sealed to a suction port providing connection to a length of tubing, which may be used to pump fluid out of the dressing or to transmit

negative pressure from a pump to the wound dressing. Additionally, RENASYS-F, RENASYS-G, RENASYS-AB, and RENASYS-F/AB, available from Smith & Nephew, are additional examples of NPWT wound dressings and systems. Another example of a multi-layer wound dressing is the ALLEVYN Life dressing, available from Smith & Nephew, which includes a moist wound environment dressing that is used to treat the wound without the use of negative pressure.

As is used herein, reduced or negative pressure levels, such as −X mmHg, represent pressure levels relative to normal ambient atmospheric pressure, which can correspond to 760 mmHg (or 1 atm, 29.93 inHg, 101.325 kPa, 14.696 psi, etc.). Accordingly, a negative pressure value of −X mmHg reflects absolute pressure that is X mmHg below 760 mmHg or, in other words, an absolute pressure of (760−X) mmHg. In addition, negative pressure that is "less" or "smaller" than X mmHg corresponds to pressure that is closer to atmospheric pressure (such as, −40 mmHg is less than −60 mmHg). Negative pressure that is "more" or "greater" than −X mmHg corresponds to pressure that is further from atmospheric pressure (such as, −80 mmHg is more than −60 mmHg). In some cases, local ambient atmospheric pressure is used as a reference point, and such local atmospheric pressure may not necessarily be, for example, 760 mmHg.

The negative pressure range for some examples of the present disclosure can be approximately −80 mmHg, or between about −20 mmHg and −200 mmHg. Note that these pressures are relative to normal ambient atmospheric pressure, which can be 760 mmHg. Thus, −200 mmHg would be about 560 mmHg in practical terms. In some cases, the pressure range can be between about −40 mmHg and −150 mmHg. Alternatively, a pressure range of up to −75 mmHg, up to −80 mmHg or over −80 mmHg can be used. Also in other examples, a pressure range of below −75 mmHg can be used. Alternatively, a pressure range of over approximately −100 mmHg, or even −150 mmHg, can be supplied by the negative pressure apparatus.

In some examples of wound closure devices described herein, increased wound contraction can lead to increased tissue expansion in the surrounding wound tissue. This effect may be increased by varying the force applied to the tissue, for example by varying the negative pressure applied to the wound over time, possibly in conjunction with increased tensile forces applied to the wound via examples of the wound closure devices. In some cases, negative pressure may be varied over time for example using a sinusoidal wave, square wave, or in synchronization with one or more patient physiological indices (such as, heartbeat). Examples of such applications where additional disclosure relating to the preceding may be found include U.S. Pat. No. 8,235,955, titled "Wound treatment apparatus and method," issued on Aug. 7, 2012; and U.S. Pat. No. 7,753,894, titled "Wound cleansing apparatus with stress," issued Jul. 13, 2010. The disclosures of both of these patents are hereby incorporated by reference in their entirety.

Examples of the wound dressings, wound dressing components, wound treatment apparatuses and methods described herein may also be used in combination or in addition to those described in International Application No. PCT/IB2013/001469, filed May 22, 2013, published as WO 2013/175306 A2 on Nov. 28, 2013, titled "APPARATUSES AND METHODS FOR NEGATIVE PRESSURE WOUND THERAPY," U.S. patent application Ser. No. 14/418,908, filed Jan. 30, 2015, published as US 2015/0190286 A1 on Jul. 9, 2015, titled "WOUND DRESSING AND METHOD OF TREATMENT," the disclosures of which are hereby incorporated by reference in their entireties. Examples of the wound dressings, wound dressing assembly, wound dressing components, wound treatment apparatuses and methods described herein may also be used in combination or in addition to those described in U.S. patent application Ser. No. 13/092,042, filed Apr. 21, 2011, published as US2011/0282309, titled "WOUND DRESSING AND METHOD OF USE," and U.S. patent application Ser. No. 14/715,527, filed May 18, 2015, published as US2016/0339158 A1 on Nov. 24, 2016, titled "FLUIDIC CONNECTOR FOR NEGATIVE PRESSURE WOUND THERAPY," the disclosure of each of which is hereby incorporated by reference in its entirety, including further details relating to examples of wound dressings, the wound dressing components and principles, and the materials used for the wound dressings.

Additionally, some examples related to TNP wound treatment comprising a wound dressing in combination with a pump or associated electronics described herein may also be used in combination or in addition to those described in International Application PCT/EP2016/059329 filed Apr. 26, 2016, published as WO 2016/174048 on Nov. 3, 2016, entitled "REDUCED PRESSURE APPARATUS AND METHODS," the disclosure of which is hereby incorporated by reference in its entirety.

NPWT System Overview

FIG. **1**A illustrates an example of a negative or reduced pressure wound treatment (or TNP) system **102** comprising a wound filler **108** placed inside a wound cavity **104**, the wound cavity sealed by a wound cover **106**. The wound filler **108** in combination with the wound cover **106** can be referred to as wound dressing. A single or multi lumen tube or conduit **112** is connected the wound cover **106** with a pump assembly **114** configured to supply reduced pressure. The wound cover **106** can be in fluidic communication with the wound cavity **104**. In any of the system examples disclosed herein, as in the example illustrated in FIG. **1**A, the pump assembly can be a canisterless pump assembly (meaning that exudate is collected in the wound dressing or is transferred via tube **112** for collection to another location). However, any of the pump assembly examples disclosed herein can be configured to include or support a canister. Additionally, in any of the system examples disclosed herein, any of the pump assembly examples can be mounted to or supported by the dressing, or adjacent to the dressing.

The wound filler **108** can be any suitable type, such as hydrophilic or hydrophobic foam, gauze, inflatable bag, and so on. The wound filler **108** can be conformable to the wound cavity **104** such that it substantially fills the cavity. The wound cover **106** can provide a substantially fluid impermeable seal over the wound cavity **104**. The wound cover **106** can have a top side and a bottom side, and the bottom side adhesively (or in any other suitable manner) seals with wound cavity **104**. The conduit **112** or lumen or any other conduit or lumen disclosed herein can be formed from polyurethane, PVC, nylon, polyethylene, silicone, or any other suitable material.

Some examples of the wound cover **106** can have a port (not shown) configured to receive an end of the conduit **112**. For example, the port can be Renays Soft Port available from Smith & Nephew. In other cases, the conduit **112** can otherwise pass through or under the wound cover **106** to supply reduced pressure to the wound cavity **104** so as to maintain a desired level of reduced pressure in the wound cavity. The conduit **112** can be any suitable article configured to provide at least a substantially sealed fluid flow pathway between the pump assembly **114** and the wound

cover **106**, so as to supply the reduced pressure provided by the pump assembly **114** to wound cavity **104**.

The wound cover **106** and the wound filler **108** can be provided as a single article or an integrated single unit. In some cases, no wound filler is provided and the wound cover by itself may be considered the wound dressing. The wound dressing may then be connected, via the conduit **112**, to a source of negative pressure, such as the pump assembly **114**. The pump assembly **114** can be miniaturized and portable, although larger conventional pumps such can also be used.

The wound cover **106** can be located over a wound site to be treated. The wound cover **106** can form a substantially sealed cavity or enclosure over the wound site. In some cases, the wound cover **106** can be configured to have a film having a high water vapour permeability to enable the evaporation of surplus fluid, and can have a superabsorbing material contained therein to safely absorb wound exudate. It will be appreciated that throughout this specification reference is made to a wound. In this sense it is to be understood that the term wound is to be broadly construed and encompasses open and closed wounds in which skin is torn, cut or punctured or where trauma causes a contusion, or any other surficial or other conditions or imperfections on the skin of a patient or otherwise that benefit from reduced pressure treatment. A wound is thus broadly defined as any damaged region of tissue where fluid may or may not be produced. Examples of such wounds include, but are not limited to, acute wounds, chronic wounds, surgical incisions and other incisions, subacute and dehisced wounds, traumatic wounds, flaps and skin grafts, lacerations, abrasions, contusions, burns, diabetic ulcers, pressure ulcers, stoma, surgical wounds, trauma and venous ulcers or the like. The components of the TNP system described herein can be particularly suited for incisional wounds that exude a small amount of wound exudate.

Some examples of the system are designed to operate without the use of an exudate canister. Some examples can be configured to support an exudate canister. In some cases, configuring the pump assembly **114** and tubing **112** so that the tubing **112** can be quickly and easily removed from the pump assembly **114** can facilitate or improve the process of dressing or pump changes, if necessary. Any of the pump examples disclosed herein can be configured to have any suitable connection between the tubing and the pump.

The pump assembly **114** can be configured to deliver negative pressure of approximately −80 mmHg, or between about −20 mmHg and −200 mmHg in some implementations. Note that these pressures are relative to normal ambient atmospheric pressure thus, −200 mmHg would be about 560 mmHg in practical terms. The pressure range can be between about −40 mmHg and −150 mmHg. Alternatively a pressure range of up to −75 mmHg, up to −80 mmHg or over −80 mmHg can be used. Also a pressure range of below −75 mmHg can be used. Alternatively a pressure range of over approximately −100 mmHg, or even −150 mmHg, can be supplied by the pump assembly **114**.

In operation, the wound filler **108** is inserted into the wound cavity **104** and wound cover **106** is placed so as to seal the wound cavity **104**. The pump assembly **114** provides a source of a negative pressure to the wound cover **106**, which is transmitted to the wound cavity **104** via the wound filler **108**. Fluid (such as, wound exudate) is drawn through the conduit **112**, and can be stored in a canister. In some cases, fluid is absorbed by the wound filler **108** or one or more absorbent layers (not shown).

Wound dressings that may be utilized with the pump assembly and other examples of the present application include Renasys-F, Renasys-G, Renasys AB, and Pico Dressings available from Smith & Nephew. Further description of such wound dressings and other components of a negative pressure wound therapy system that may be used with the pump assembly and other examples of the present application are found in U.S. Patent Publication Nos. 2011/0213287, 2011/0282309, 2012/0116334, 2012/0136325, and 2013/0110058, which are incorporated by reference in their entirety. In other examples, other suitable wound dressings can be utilized.

Wound Dressing Overview

FIG. **1**B illustrates an example cross-section through a wound dressing **155**. FIG. **1**B also illustrates an example fluidic connector **116**. The wound dressing **155** can be similar to the wound dressing described in International Patent Publication WO2013175306 A2, which is incorporated by reference in its entirety. Alternatively, the wound dressing **155** can be any wound dressing example disclosed herein or any combination of features of any number of wound dressing examples disclosed herein, can be located over a wound site to be treated. The wound dressing **155** may be placed as to form a sealed cavity over the wound, such as the wound cavity **104**. In some cases, the wound dressing **155** includes a top or cover layer, or backing layer **220** attached to an optional wound contact layer **222**, both of which are described in greater detail below. These two layers **220**, **222** can be joined or sealed together so as to define an interior space or chamber. This interior space or chamber may comprise additional structures that may be adapted to distribute or transmit negative pressure, store wound exudate and other fluids removed from the wound, and other functions which will be explained in greater detail below. Examples of such structures, described below, include a transmission layer **226** and an absorbent layer **221**.

As used herein the upper layer, top layer, or layer above refers to a layer furthest from the surface of the skin or wound while the dressing is in use and positioned over the wound. Accordingly, the lower surface, lower layer, bottom layer, or layer below refers to the layer that is closest to the surface of the skin or wound while the dressing is in use and positioned over the wound.

The wound contact layer **222** can be a polyurethane layer or polyethylene layer or other flexible layer which is perforated, for example via a hot pin process, laser ablation process, ultrasound process or in some other way or otherwise made permeable to liquid and gas. The wound contact layer **222** has a lower surface **224** (for example, facing the wound) and an upper surface **223** (for example, facing away from the wound). The perforations **225** can comprise through holes in the wound contact layer **222** which enable fluid to flow through the layer **222**. The wound contact layer **222** helps prevent tissue ingrowth into the other material of the wound dressing. In some cases, the perforations are small enough to meet this requirement while still allowing fluid to flow therethrough. For example, perforations formed as slits or holes having a size ranging from 0.025 mm to 1.2 mm are considered small enough to help prevent tissue ingrowth into the wound dressing while allowing wound exudate to flow into the dressing. In some configurations, the wound contact layer **222** may help maintain the integrity of the entire dressing **155** while also creating an air tight seal around the absorbent pad in order to maintain negative pressure at the wound. In some cases, the wound contact layer is configured to allow unidirectional or substantially one-way or unidirectional flow of fluid through the wound contact layer when negative pressure is applied to the wound. For example, the wound contact layer can permit

fluid to flow away from the wound through the wound contact layer, but not allow fluid to flow back toward the wound. In certain case, the perforations in the wound contact layer are configured to permit such one-way or unidirectional flow of fluid through the wound contact layer.

Some examples of the wound contact layer **222** may also act as a carrier for an optional lower and upper adhesive layer (not shown). For example, a lower pressure sensitive adhesive may be provided on the lower surface **224** of the wound dressing **155** whilst an upper pressure sensitive adhesive layer may be provided on the upper surface **223** of the wound contact layer. The pressure sensitive adhesive, which may be a silicone, hot melt, hydrocolloid or acrylic based adhesive or other such adhesives, may be formed on both sides or optionally on a selected one or none of the sides of the wound contact layer. When a lower pressure sensitive adhesive layer is utilized may be helpful to adhere the wound dressing **155** to the skin around a wound site. In some cases, the wound contact layer may comprise perforated polyurethane film. The lower surface of the film may be provided with a silicone pressure sensitive adhesive and the upper surface may be provided with an acrylic pressure sensitive adhesive, which may help the dressing maintain its integrity. In some cases, a polyurethane film layer may be provided with an adhesive layer on both its upper surface and lower surface, and all three layers may be perforated together.

A layer **226** of porous material can be located above the wound contact layer **222**. This porous layer, or transmission layer, **226** allows transmission of fluid including liquid and gas away from a wound site into upper layers of the wound dressing. In particular, the transmission layer **226** can ensure that an open air channel can be maintained to communicate negative pressure over the wound area even when the absorbent layer has absorbed substantial amounts of exudates. The layer **226** can remain open under the typical pressures that will be applied during negative pressure wound therapy as described above, so that the whole wound site sees an equalized negative pressure. The layer **226** may be formed of a material having a three dimensional structure. For example, a knitted or woven spacer fabric (for example Baltex 7970 weft knitted polyester) or a non-woven fabric could be used.

In some cases, the transmission layer **226** comprises a 3D polyester spacer fabric layer including a top layer (that is to say, a layer distal from the wound-bed in use) which is a 84/144 textured polyester, and a bottom layer (that is to say, a layer which lies proximate to the wound bed in use) which is a 10 denier flat polyester and a third layer formed sandwiched between these two layers which is a region defined by a knitted polyester viscose, cellulose or the like monofilament fiber. Other materials and other linear mass densities of fiber could of course be used.

Whilst reference is made throughout this disclosure to a monofilament fiber it will be appreciated that a multistrand alternative could of course be utilized. The top spacer fabric thus has more filaments in a yarn used to form it than the number of filaments making up the yarn used to form the bottom spacer fabric layer.

This differential between filament counts in the spaced apart layers helps control moisture flow across the transmission layer. Particularly, by having a filament count greater in the top layer, that is to say, the top layer is made from a yarn having more filaments than the yarn used in the bottom layer, liquid tends to be wicked along the top layer more than the bottom layer. In use, this differential tends to draw liquid away from the wound bed and into a central region of the dressing where the absorbent layer **221** helps lock the liquid away or itself wicks the liquid onwards towards the cover layer where it can be transpired.

In some cases, to improve the liquid flow across the transmission layer **226** (that is to say perpendicular to the channel region formed between the top and bottom spacer layers, the 3D fabric may be treated with a dry cleaning agent (such as, but not limited to, Perchloro Ethylene) to help remove any manufacturing products such as mineral oils, fats or waxes used previously which might interfere with the hydrophilic capabilities of the transmission layer. An additional manufacturing step can subsequently be carried in which the 3D spacer fabric is washed in a hydrophilic agent (such as, but not limited to, Feran Ice **30***g*/l available from the Rudolph Group). This process step helps ensure that the surface tension on the materials is so low that liquid such as water can enter the fabric as soon as it contacts the 3D knit fabric. This also aids in controlling the flow of the liquid insult component of any exudates.

A layer **221** of absorbent material can be provided above the transmission layer **226**. The absorbent material, which comprise a foam or non-woven natural or synthetic material, and which may optionally comprise a super-absorbent material, forms a reservoir for fluid, particularly liquid, removed from the wound site. In some cases, the layer **221** may also aid in drawing fluids towards the backing layer **220**.

The material of the absorbent layer **221** may also prevent liquid collected in the wound dressing **155** from flowing freely within the dressing, and can act so as to contain any liquid collected within the dressing. The absorbent layer **221** also helps distribute fluid throughout the layer via a wicking action so that fluid is drawn from the wound site and stored throughout the absorbent layer. This helps prevent agglomeration in areas of the absorbent layer. The capacity of the absorbent material must be sufficient to manage the exudates flow rate of a wound when negative pressure is applied. Since in use the absorbent layer experiences negative pressures the material of the absorbent layer is chosen to absorb liquid under such circumstances. A number of materials exist that are able to absorb liquid when under negative pressure, for example superabsorber material. The absorbent layer **221** may typically be manufactured from ALLEVYN™ foam, Freudenberg 114-224-4 or Chem-Posite™11C-450. In some cases, the absorbent layer **221** may comprise a composite comprising superabsorbent powder, fibrous material such as cellulose, and bonding fibers. In some cases, the composite is an airlaid, thermally-bonded composite.

In some cases, the absorbent layer **221** is a layer of non-woven cellulose fibers having super-absorbent material in the form of dry particles dispersed throughout. Use of the cellulose fibers introduces fast wicking elements which help quickly and evenly distribute liquid taken up by the dressing. The juxtaposition of multiple strand-like fibers leads to strong capillary action in the fibrous pad which helps distribute liquid. In this way, the super-absorbent material is efficiently supplied with liquid. The wicking action also assists in bringing liquid into contact with the upper cover layer to aid increase transpiration rates of the dressing.

An aperture, hole, or orifice **227** can be provided in the backing layer **220** to allow a negative pressure to be applied to the dressing **155**. In some cases, the fluidic connector **116** is attached or sealed to the top of the backing layer **220** over the orifice **227** made into the dressing **155**, and communicates negative pressure through the orifice **227**. A length of tubing may be coupled at a first end to the fluidic connector **116** and at a second end to a pump unit (not shown) to allow

fluids to be pumped out of the dressing. Where the fluidic connector is adhered to the top layer of the wound dressing, a length of tubing may be coupled at a first end of the fluidic connector such that the tubing, or conduit, extends away from the fluidic connector parallel or substantially to the top surface of the dressing. The fluidic connector **116** may be adhered and sealed to the backing layer **220** using an adhesive such as an acrylic, cyanoacrylate, epoxy, UV curable or hot melt adhesive. The fluidic connector **116** may be formed from a soft polymer, for example a polyethylene, a polyvinyl chloride, a silicone or polyurethane having a hardness of 30 to 90 on the Shore A scale. In some cases, the fluidic connector **116** may be made from a soft or conformable material.

In some cases, the absorbent layer **221** includes at least one through hole **228** located so as to underlie the fluidic connector **116**. The through hole **228** may in some cases be the same size as the opening **227** in the backing layer, or may be bigger or smaller. As illustrated in FIG. **1**B a single through hole can be used to produce an opening underlying the fluidic connector **116**. It will be appreciated that multiple openings could alternatively be utilized. Additionally should more than one port be utilized according to certain examples of the present disclosure one or multiple openings may be made in the absorbent layer and the obscuring layer in registration with each respective fluidic connector. Although not essential to certain examples of the present disclosure the use of through holes in the super-absorbent layer may provide a fluid flow pathway which remains unblocked in particular when the absorbent layer is near saturation.

The aperture or through-hole **228** can be provided in the absorbent layer **221** beneath the orifice **227** such that the orifice is connected directly to the transmission layer **226** as illustrated in FIG. **1**B. This allows the negative pressure applied to the fluidic connector **116** to be communicated to the transmission layer **226** without passing through the absorbent layer **221**. This ensures that the negative pressure applied to the wound site is not inhibited by the absorbent layer as it absorbs wound exudates. In other cases, no aperture may be provided in the absorbent layer **221**, or alternatively a plurality of apertures underlying the orifice **227** may be provided. In further alternative examples, additional layers such as another transmission layer or an obscuring layer such as described in International Patent Publication WO2014020440, the entirety of which is hereby incorporated by reference, may be provided over the absorbent layer **221** and beneath the backing layer **220**.

The backing layer **220** is can be gas impermeable, but moisture vapor permeable, and can extend across the width of the wound dressing **155**. The backing layer **220**, which may for example be a polyurethane film (for example, Elastollan SP9109) having a pressure sensitive adhesive on one side, is impermeable to gas and this layer thus operates to cover the wound and to seal a wound cavity over which the wound dressing is placed. In this way an effective chamber is made between the backing layer **220** and a wound site where a negative pressure can be established. The backing layer **220** can be sealed to the wound contact layer **222** in a border region around the circumference of the dressing, ensuring that no air is drawn in through the border area, for example via adhesive or welding techniques. The backing layer **220** protects the wound from external bacterial contamination (bacterial barrier) and allows liquid from wound exudates to be transferred through the layer and evaporated from the film outer surface. The backing layer **220** can include two layers; a polyurethane film and an adhesive pattern spread onto the film. The polyurethane film can be moisture vapor permeable and may be manufactured from a material that has an increased water transmission rate when wet. In some cases, the moisture vapor permeability of the backing layer increases when the backing layer becomes wet. The moisture vapor permeability of the wet backing layer may be up to about ten times more than the moisture vapor permeability of the dry backing layer.

The absorbent layer **221** may be of a greater area than the transmission layer **226**, such that the absorbent layer overlaps the edges of the transmission layer **226**, thereby ensuring that the transmission layer does not contact the backing layer **220**. This provides an outer channel of the absorbent layer **221** that is in direct contact with the wound contact layer **222**, which aids more rapid absorption of exudates to the absorbent layer. Furthermore, this outer channel ensures that no liquid is able to pool around the circumference of the wound cavity, which may otherwise seep through the seal around the perimeter of the dressing leading to the formation of leaks. As illustrated in FIG. **1**B, the absorbent layer **221** may define a smaller perimeter than that of the backing layer **220**, such that a boundary or border region is defined between the edge of the absorbent layer **221** and the edge of the backing layer **220**.

As shown in FIG. **1**B, one example of the wound dressing **155** comprises an aperture **228** in the absorbent layer **221** situated underneath the fluidic connector **116**. In use, for example when negative pressure is applied to the dressing **155**, a wound facing portion of the fluidic connector may thus come into contact with the transmission layer **226**, which can thus aid in transmitting negative pressure to the wound site even when the absorbent layer **221** is filled with wound fluids. Some examples may have the backing layer **220** be at least partly adhered to the transmission layer **226**. In some cases, the aperture **228** is at least 1-2 mm larger than the diameter of the wound facing portion of the fluidic connector **11**, or the orifice **227**.

For example, in examples with a single fluidic connector **116** and through hole, it may be preferable for the fluidic connector **116** and through hole to be located in an off-center position. Such a location may permit the dressing **155** to be positioned onto a patient such that the fluidic connector **116** is raised in relation to the remainder of the dressing **155**. So positioned, the fluidic connector **116** and the filter **214** may be less likely to come into contact with wound fluids that could prematurely occlude the filter **214** so as to impair the transmission of negative pressure to the wound site.

Turning now to the fluidic connector **116**, some examples include a sealing surface **216**, a bridge **211** with a proximal end (closer to the negative pressure source) and a distal end **140**, and a filter **214**. The sealing surface **216** can form the applicator that is sealed to the top surface of the wound dressing. In some cases, a bottom layer of the fluidic connector **116** may comprise the sealing surface **216**. The fluidic connector **116** may further comprise an upper surface vertically spaced from the sealing surface **216**, which in some examples is defined by a separate upper layer of the fluidic connector. In other cases, the upper surface and the lower surface may be formed from the same piece of material. In some cases, the sealing surface **216** may comprise at least one aperture **229** therein to communicate with the wound dressing. In some cases, the filter **214** may be positioned across the opening **229** in the sealing surface, and may span the entire opening **229**. The sealing surface **216** may be configured for sealing the fluidic connector to the cover layer of the wound dressing, and may comprise an adhesive or weld. In some cases, the sealing surface **216** may be placed over an orifice in the cover layer with optional

spacer elements **215** configured to create a gap between the filter **214** and the transmission layer **226**. In other cases, the sealing surface **216** may be positioned over an orifice in the cover layer and an aperture in the absorbent layer **220**, permitting the fluidic connector **116** to provide air flow through the transmission layer **226**. In some cases, the bridge **211** may comprise a first fluid passage **212** in communication with a source of negative pressure, the first fluid passage **212** comprising a porous material, such as a 3D knitted material, which may be the same or different than the porous layer **226** described previously. The bridge **211** can be encapsulated by at least one flexible film layer **208**, **210** having a proximal and distal end and configured to surround the first fluid passage **212**, the distal end of the flexible film being connected the sealing surface **216**. The filter **214** is configured to substantially prevent wound exudate from entering the bridge, and spacer elements **215** are configured to prevent the fluidic connector from contacting the transmission layer **226**. These elements will be described in greater detail below.

Some examples may further comprise an optional second fluid passage positioned above the first fluid passage **212**. For example, some examples may provide for an air leak may be disposed at the proximal end of the top layer that is configured to provide an air path into the first fluid passage **212** and dressing **155** similar to the suction adapter as described in U.S. Pat. No. 8,801,685, which is incorporated by reference herein in its entirety.

In some cases, the fluid passage **212** is constructed from a compliant material that is flexible and that also permits fluid to pass through it if the spacer is kinked or folded over. Suitable materials for the fluid passage **212** include without limitation foams, including open-cell foams such as polyethylene or polyurethane foam, meshes, 3D knitted fabrics, non-woven materials, and fluid channels. In some cases, the fluid passage **212** may be constructed from materials similar to those described above in relation to the transmission layer **226**. Advantageously, such materials used in the fluid passage **212** not only permit greater patient comfort, but may also provide greater kink resistance, such that the fluid passage **212** is still able to transfer fluid from the wound toward the source of negative pressure while being kinked or bent.

In some cases, the fluid passage **212** may be comprised of a wicking fabric, for example a knitted or woven spacer fabric (such as a knitted polyester 3D fabric, Baltex 7970®, or Gehring 879®) or a nonwoven fabric. These materials selected can be suited to channeling wound exudate away from the wound and for transmitting negative pressure or vented air to the wound site, and may also confer a degree of kinking or occlusion resistance to the fluid passage **212**. In some cases, the wicking fabric may have a three-dimensional structure, which in some cases may aid in wicking fluid or transmitting negative pressure. In certain examples, including wicking fabrics, these materials remain open and capable of communicating negative pressure to a wound area under the typical pressures used in negative pressure therapy, for example between −40 to −150 mmHg. In some cases, the wicking fabric may comprise several layers of material stacked or layered over each other, which may in some cases be useful in preventing the fluid passage **212** from collapsing under the application of negative pressure. In other cases, the wicking fabric used in the fluid passage **212** may be between 1.5 mm and 6 mm; more preferably, the wicking fabric may be between 3 mm and 6 mm thick, and may be comprised of either one or several individual layers of wicking fabric. In other cases, the fluid passage **212** may be between 1.2-3 mm thick, and preferably thicker than 1.5 mm. Some examples, for example a suction adapter used with a dressing which retains liquid such as wound exudate, may employ hydrophobic layers in the fluid passage **212**, and only gases may travel through the fluid passage **212**. Additionally, and as described previously, the materials used in the system can be conformable and soft, which may help to avoid pressure ulcers and other complications which may result from a wound treatment system being pressed against the skin of a patient.

In some cases, the filter element **214** is impermeable to liquids, but permeable to gases, and is provided to act as a liquid barrier and to ensure that no liquids are able to escape from the wound dressing **155**. The filter element **214** may also function as a bacterial barrier. Typically the pore size is 0.2 μm. Suitable materials for the filter material of the filter element **214** include 0.2 micron Gore™ expanded PTFE from the MMT range, PALL Versapore™ 200R, and Donaldson™ TX6628. Larger pore sizes can also be used but these may require a secondary filter layer to ensure full bioburden containment. As wound fluid contains lipids it is preferable, though not essential, to use an oleophobic filter membrane for example 1.0 micron MMT-332 prior to 0.2 micron MMT-323. This prevents the lipids from blocking the hydrophobic filter. The filter element can be attached or sealed to the port or the cover film over the orifice. For example, the filter element **214** may be molded into the fluidic connector **116**, or may be adhered to one or both of the top of the cover layer and bottom of the suction adapter **160** using an adhesive such as, but not limited to, a UV cured adhesive.

It will be understood that other types of material could be used for the filter element **214**. More generally a microporous membrane can be used which is a thin, flat sheet of polymeric material, this contains billions of microscopic pores. Depending upon the membrane chosen these pores can range in size from 0.01 to more than 10 micrometers. Microporous membranes are available in both hydrophilic (water filtering) and hydrophobic (water repellent) forms. In some cases, filter element **214** comprises a support layer and an acrylic co-polymer membrane formed on the support layer. In some cases, the wound dressing **155** according to certain examples uses microporous hydrophobic membranes (MHMs). Numerous polymers may be employed to form MHMs. For example, the MHMS may be formed from one or more of PTFE, polypropylene, PVDF and acrylic copolymer. All of these optional polymers can be treated in order to obtain specific surface characteristics that can be both hydrophobic and oleophobic. As such these will repel liquids with low surface tensions such as multi-vitamin infusions, lipids, surfactants, oils and organic solvents.

MHMs block liquids whilst allowing air to flow through the membranes. They are also highly efficient air filters eliminating potentially infectious aerosols and particles. A single piece of MEM is well known as an option to replace mechanical valves or vents. Incorporation of MHMs can thus reduce product assembly costs improving profits and costs/benefit ratio to a patient.

The filter element **214** may also include an odor absorbent material, for example activated charcoal, carbon fiber cloth or Vitec Carbotec-RT Q2003073 foam, or the like. For example, an odor absorbent material may form a layer of the filter element **214** or may be sandwiched between microporous hydrophobic membranes within the filter element. The filter element **214** thus enables gas to be exhausted through the orifice. Liquid, particulates and pathogens however are contained in the dressing.

The wound dressing **155** may comprise spacer elements **215** in conjunction with the fluidic connector **116** and the filter **214**. With the addition of such spacer elements **215** the fluidic connector **116** and filter **214** may be supported out of direct contact with the absorbent layer **220** or the transmission layer **226**. The absorbent layer **220** may also act as an additional spacer element to keep the filter **214** from contacting the transmission layer **226**. Accordingly, with such a configuration contact of the filter **214** with the transmission layer **226** and wound fluids during use may thus be minimized.

Similar to the examples of wound dressings described above, some wound dressings comprise a perforated wound contact layer with silicone adhesive on the skin-contact face and acrylic adhesive on the reverse. Above this bordered layer sits a transmission layer or a 3D spacer fabric pad. Above the transmission layer, sits an absorbent layer. The absorbent layer can include a superabsorbent non-woven (NW) pad. The absorbent layer can over-border the transmission layer by approximately 5 mm at the perimeter. The absorbent layer can have an aperture or through-hole toward one end. The aperture can be about 10 mm in diameter. Over the transmission layer and absorbent layer lies a backing layer. The backing layer can be a high moisture vapor transmission rate (MVTR) film, pattern coated with acrylic adhesive. The high MVTR film and wound contact layer encapsulate the transmission layer and absorbent layer, creating a perimeter border of approximately 20 mm. The backing layer can have a 10 mm aperture that overlies the aperture in the absorbent layer. Above the hole can be bonded a fluidic connector that comprises a liquid-impermeable, gas-permeable semi-permeable membrane (SPM) or filter that overlies the aforementioned apertures.

FIGS. **1C-1D** illustrate examples of a negative pressure wound treatment system **10** employing a wound dressing **100** in conjunction with a fluidic connector **110**. Here, the fluidic connector **110** may comprise an elongate conduit, for example, a bridge **120** having a proximal end **130** and a distal end **140**, and an applicator **180** at the distal end **140** of the bridge **120**. An optional coupling **160** can be disposed at the proximal end **130** of the bridge **120**. A cap **170** may be provided with the system (and can in some cases, as illustrated, be attached to the coupling **160**). The cap **170** can be useful in preventing fluids from leaking out of the proximal end **130**. The negative pressure wound treatment system **10** may include a source of negative pressure such as a pump or negative pressure unit **150** capable of supplying negative pressure. The pump may comprise a canister or other container for the storage of wound exudates and other fluids that may be removed from the wound. A canister or container may also be provided separate from the pump. In some cases, such as illustrated in FIGS. **1A-1B**, the pump **150** can be a canisterless pump such as the PICO™ pump, as sold by Smith & Nephew. The pump **150** may be connected to the coupling **160** via a tube **190**, or the pump **150** may be connected directly to the coupling **160** or directly to the bridge **120**. In use, the wound dressing **100** is placed over a suitably-prepared wound, which may in some cases be filled with a wound packing material such as foam or gauze. The applicator **180** of the fluidic connector **110** has a sealing surface that is placed over an aperture in the wound dressing **100** and is sealed to the top surface of the wound dressing **100**. Either before, during, or after connection of the fluidic connector **110** to the wound dressing **100**, the pump **150** is connected via the tube **190** to the coupling **160**, or is connected directly to the coupling **160** or to the bridge **120**. The pump is then activated, thereby supplying negative pressure to the wound. Application of negative pressure may be applied until a desired level of healing of the wound is achieved.

As shown in FIG. **1E**, the fluidic connector **110** comprises an enlarged distal end, or head **140** that is in fluidic communication with the wound dressing **100** as will be described in further detail below. In one example, the enlarged distal end has a round or circular shape. The head **140** is illustrated here as being positioned near an edge of the wound dressing **100**, but may also be positioned at any location on the dressing. For example, some examples may provide for a centrally or off-centered location not on or near an edge or corner of the wound dressing **100**. In some cases, the wound dressing **100** may comprise two or more fluidic connectors **110**, each comprising one or more heads **140**, in fluidic communication therewith. In an example, the head **140** may measure 30 mm along its widest edge. The head **140** forms at least in part the applicator **180**, described above, that is configured to seal against a top surface of the wound dressing.

Turning to FIG. **1F**, treatment of other wound types, such as larger abdominal wounds, with negative pressure in certain examples uses a negative pressure treatment system **101** as illustrated schematically here. In this example, a wound **126**, illustrated here as an abdominal wound, may benefit from treatment with negative pressure. Such abdominal wounds may be a result of, for example, an accident or due to surgical intervention. In some cases, medical conditions such as abdominal compartment syndrome, abdominal hypertension, sepsis, or fluid edema may require decompression of the abdomen with a surgical incision through the abdominal wall to expose the peritoneal space, after which the opening may need to be maintained in an open, accessible state until the condition resolves. Other conditions may also necessitate that an opening—particularly in the abdominal cavity—remain open, for example if multiple surgical procedures are required (possibly incidental to trauma), or there is evidence of clinical conditions such as peritonitis or necrotizing fasciitis.

In cases where there is a wound, particularly in the abdomen, management of possible complications relating to the exposure of organs and the peritoneal space is desired, whether or not the wound is to remain open or if it will be closed. Therapy, preferably using the application of negative pressure, can be targeted to minimize the risk of infection, while promoting tissue viability and the removal of deleterious substances from the wound. The application of reduced or negative pressure to a wound has been found to generally promote faster healing, increased blood flow, decreased bacterial burden, increased rate of granulation tissue formation, to stimulate the proliferation of fibroblasts, stimulate the proliferation of endothelial cells, close chronic open wounds, inhibit burn penetration, or enhance flap and graft attachment, among other things. It has also been reported that wounds that have exhibited positive response to treatment by the application of negative pressure include infected open wounds, decubitus ulcers, dehisced incisions, partial thickness burns, and various lesions to which flaps or grafts have been attached. Consequently, the application of negative pressure to a wound **106** can be beneficial to a patient.

Accordingly, certain examples provide for a wound contact layer **105** to be placed over the wound **126**. The wound contact layer can also be referred to as an organ protection layer or a tissue protection layer. Preferably, the wound contact layer **105** can be a thin, flexible material which will not adhere to the wound or the exposed viscera in close proximity. For example, polymers such as polyurethane,

polyethylene, polytetrafluoroethylene, or blends thereof may be used. In one example, the wound contact layer is permeable. For example, the wound contact layer **105** can be provided with openings, such as holes, slits, or channels, to allow the removal of fluids from the wound **126** or the transmittal of negative pressure to the wound **126**. Additional examples of the wound contact layer **105** are described in further detail below.

Certain examples of the negative pressure wound treatment system **10** may also use a porous wound filler **103**, which can be disposed over the wound contact layer **105**. This pad **103** can be constructed from a porous material, for example foam, that is soft, resiliently flexible, and generally conformable to the wound **126**. Such a foam can include an open-celled and reticulated foam made, for example, of a polymer. Suitable foams include foams composed of, for example, polyurethane, silicone, and polyvinyl alcohol. Preferably, this pad **103** can channel wound exudate and other fluids through itself when negative pressure is applied to the wound. Some pads **103** may include preformed channels or openings for such purposes. In certain examples, the pad **103** may have a thickness between about one inch and about two inches. The pad may also have a length of between about 16 and 17 inches, and a width of between about 11 and 12 inches. In other examples, the thickness, width, or length can have other suitable values. Other examples of wound fillers that may be used in place of or in addition to the pad **103** are discussed in further detail below.

Preferably, a drape **107** is used to seal the wound **126**. The drape **107** can be at least partially liquid impermeable, such that at least a partial negative pressure may be maintained at the wound. Suitable materials for the drape **107** include, without limitation, synthetic polymeric materials that do not significantly absorb aqueous fluids, including polyolefins such as polyethylene and polypropylene, polyurethanes, polysiloxanes, polyamides, polyesters, and other copolymers and mixtures thereof. The materials used in the drape may be hydrophobic or hydrophilic. Examples of suitable materials include Transeal® available from DeRoyal and OpSite® available from Smith & Nephew. In order to aid patient comfort and avoid skin maceration, the drapes in certain examples are at least partly breathable, such that water vapor is able to pass through without remaining trapped under the dressing. An adhesive layer may be provided on at least a portion the underside of the drape **107** to secure the drape to the skin of the patient, although certain examples may instead use a separate adhesive or adhesive strip. Optionally, a release layer may be disposed over the adhesive layer to protect it prior to use and to facilitate handling the drape **107**; in some cases, the release layer may be composed of multiple sections.

The negative pressure wound treatment system **10** can be connected to a source of negative pressure, for example a pump. One example of a suitable pump is the Renasys EZ pump available from Smith & Nephew. The drape **107** may be connected to the source of negative pressure via a conduit **122**. The conduit **122** may be connected to a port **113** situated over an aperture **109** in the drape **107**, or else the conduit **122** may be connected directly through the aperture **109** without the use of a port. In a further alternative, the conduit may pass underneath the drape and extend from a side of the drape. U.S. Pat. No. 7,524,315 discloses other similar aspects of negative pressure systems and is hereby incorporated by reference in its entirety and should be considered a part of this specification.

In many applications, a container or other storage unit **115** may be interposed between the source of negative pressure **124** and the conduit **122** so as to permit wound exudate and other fluids removed from the wound to be stored without entering the source of negative pressure. Certain types of negative pressure sources—for example, peristaltic pumps—may also permit a container **115** to be placed after the source of negative pressure **124**. Some examples may also use a filter to prevent fluids, aerosols, and other microbial contaminants from leaving the container **115** or entering the source of negative pressure **124**. Further examples may also include a shut-off valve or occluding hydrophobic or oleophobic filter in the container to prevent overflow; other examples may include sensing means, such as capacitive sensors or other fluid level detectors that act to stop or shut off the source of negative pressure should the level of fluid in the container be nearing capacity. At the pump exhaust, it may also be preferable to provide an odor filter, such as an activated charcoal canister.

FIG. **1**G illustrates various examples of a wound dressing that can be used for healing a wound without negative pressure. As shown in the dressings of FIG. **1**G, the wound dressings can have multiple layers similar to the dressings described with reference to FIGS. **1**C-**1**F except the dressings of FIG. **1**G do not include a port or fluidic connector. The wound dressings of FIG. **1**G can include a cover layer and wound contact layer as described herein. The wound dressing can include various layers positioned between the wound contact layer and cover layer. For example, the dressing can include one or more absorbent layers or one or more transmission layers as described herein with reference to FIGS. **1**C-**1**F. Additionally, some examples related to wound treatment comprising a wound dressing described herein may also be used in combination or in addition to those described in U.S. Application Publication No. 2014/0249495, filed May 21, 2014, entitled "WOUND DRESSING AND METHOD OF TREATMENT" the disclosure of which are hereby incorporated by reference in its entirety, including further details relating to examples of wound dressings, the wound dressing components and principles, and the materials used for the wound dressings.

Wound Dressing with Sensors

A wound dressing that incorporates a number of sensors can be utilized in order to monitor characteristics of a wound as it heals. Collecting data from the wounds that heal well, and from those that do not, can provide useful insights towards identifying measurands to indicate whether a wound is on a healing trajectory.

In some implementations, a number of sensor technologies can be used in wound dressings or one or more components forming part of an overall wound dressing assembly. For example, as illustrated in FIGS. **2** and **3**D, which depict example wound dressings **250** and **320** with sensor arrays, one or more sensors can be incorporated onto or into a wound contact layer, which may be a perforated wound contact layer as shown in FIG. **3**D. The wound contact layer in FIGS. **2** and **3**D is illustrated as having a square shape, but it will be appreciated that the wound contact layer may have other shapes such as rectangular, circular, oval, etc. In some cases, the sensor integrated wound contact layer can be provided as an individual material layer that is placed over the wound area and then covered by a wound dressing assembly or components of a wound dressing assembly, such as gauze, foam or other wound packing material, a superabsorbent layer, a drape, a fully integrated dressing like the Pico or Allevyn Life dressing, etc. In other cases, the sensor integrated wound contact layer may be part of a single unit dressing such as described herein.

The sensor-integrated wound contact layer can be placed in contact with the wound and will allow fluid to pass through the contact layer while causing little to no damage to the tissue in the wound. The sensor-integrated wound contact layer can be made of a flexible material such as silicone and can incorporate antimicrobials or other therapeutic agents known in the art. In some cases, the sensor-integrated wound contact layer can incorporate adhesives that adhere to wet or dry tissue. In some cases, the sensors or sensor array can be incorporated into or encapsulated within other components of the wound dressing such as the absorbent layer or spacer layer described above.

As shown in FIGS. **2** and **3**D, five sensors can be used, including, for instance, sensors for temperature (such as, 25 thermistor sensors, in a 5×5 array, ~20 mm pitch), oxygen saturation or SpO2 (such as, 4 or 5 SpO2 sensors, in a single line from the center of the wound contact layer to the edge thereof, 10 mm pitch), tissue color (such as, 10 optical sensors, in 2×5 array, ~20 mm pitch; not all 5 sensors in each row of the array need be aligned), pH (such as, by measuring color of a pH sensitive pad, optionally using the same optical sensors as for tissue color), and conductivity (such as, 9 conductivity contacts, in a 3×3 array, ~40 mm pitch). As shown in FIG. **3**A, the SpO2 sensors can be arranged in a single line from the center of or near the center of the wound contact layer to the edge of the wound contact layer. The line of SpO2 sensors can allow the sensor to take measurements in the middle of the wound, at the edge or the wound, or on intact skin to measure changes between the various regions. In some cases, the wound contact layer or sensor array can be larger than the size of the wound to cover the entire surface area of the wound as well as the surrounding intact skin. The larger size of the wound contact layer or sensor array and the multiple sensors can provide more information about the wound area than if the sensor was only placed in the center of the wound or in only one area at a time.

The sensors can be incorporated onto flexible circuit boards formed of flexible polymers including polyamide, polyimide (PI), polyester, polyethylene naphthalate (PEN), polyetherimide (PEI), along with various fluropolymers (FEP) and copolymers, or any material known in the art. The sensor array can be incorporated into a two-layer flexible circuit. In some cases, the circuit board can be a multi-layer flexible circuit board. In some cases, these flexible circuits can be incorporated into any layer of the wound dressing. In some cases, a flexible circuit can be incorporated into a wound contact layer. For example, the flexible circuit can be incorporated into a wound contact layer similar to the wound contact layer described with reference to FIG. **1**B. The wound contact layer can have cutouts or slits that allow for one or more sensors to protrude out of the lower surface of the wound contact layer and contact the wound area directly.

In some cases, the sensor-integrated wound contact layer can include a first and second wound contact layer with the flexible circuit board sandwiched between the two layers of wound contact layer material. The first wound contact layer has a lower surface intended to be in contact with the wound and an upper surface intended to be in contact with flexible circuit board. The second wound contact layer has a lower surface intended to be in contact with the flexible circuit board and an upper surface intended to be in contact with a wound dressings or one or more components forming part of an overall wound dressing assembly. The upper surface of the first wound contact layer and the lower surface of the second wound contact layer can be adhered together with the flexible circuit board sandwiched between the two layers.

In some cases, the one or more sensors of the flexible circuit board can be fully encapsulated or covered by the wound contact layers to prevent contact with moisture or fluid in the wound. In some cases, the first wound contact layer can have cutouts or slits that allow for one or more sensors to protrude out of the lower surface and contact the wound area directly. For example, the one or more SpO2 sensors as shown in FIG. **3**D are shown protruding out the bottom surface of the wound contact layer. In some cases, the SpO2 sensors can be mounted directly on a lower surface of the first wound contact layer. Some or all of the sensors and electrical or electronic component(s) may be potted or encapsulated (for example, rendered waterproof or liquid-proof) with a polymer, for example, silicon or epoxy based polymers. The encapsulation with a polymer can prevent ingress of fluid and leaching of chemicals from the components. In some cases, the wound contact layer material can seal the components from water ingress and leaching of chemicals.

In some cases, gathering and processing information related to the wound can utilize three components, including a sensor array, a control or processing module, and software. These components are described in more detail herein.

FIG. **3**A illustrates a flexible sensor array circuit board **300** that includes a sensor array portion **301**, a tail portion **302**, and a connector pad end portion **303** according to some cases. The sensor array portion **301** can include the sensors and associated circuitry. The sensor array circuit board **300** can include a long tail portion **302** extending from the sensor array portion **301**. The connector pad end portion **303** can be enabled to connect to a control module or other processing unit to receive the data from the sensor array circuit. The long tail portion **302** can allow the control module to be placed distant from the wound, such as for example in a more convenient location away from the wound.

FIG. **3**B illustrates examples of the flexible circuit boards with four different sensor array geometries **301**A, **301**B, **301**C, and **301**D. The illustrated examples include tail portions **302**A, **302**B. **302**C, and **302**D. In some cases, four different sensor array geometries shown can be implemented in flexible circuits. While FIG. **3**B show four different sensor array formats and configurations, the design **301**B and **302**B also includes the connector pads end portion **303** configured to provide electrical or electronic connection between the sponsor array **301**B and a control module. One or more of the designs in **301**A, **301**C, or **301**D can also include a connector pads end portion, such as the portion **303**, to allow flexible circuit boards **301**A, **301**C, or **301**D to communicate with a control module or other processing unit. In some cases, the sensor array communicates with the control module wirelessly and the tail portion may be omitted.

FIG. **3**C shows the sensor array portion **301**B of the sensor array design shown of FIG. **3**B in more detail. In any one or more of the examples of FIG. **2** or **3**A-**3**D, the sensor array portion can include a plurality of portions that extend either around a perimeter of a wound dressing component such as a wound contact layer, or inward from an outer edge of the wound dressing component. For example, the illustrated examples include a plurality of linearly extending portions that may be parallel to edges of a wound dressing component, and in some cases, follow the entire perimeter of the wound dressing component. In some cases, the sensor array portion may comprise a first plurality of parallel linearly extending portions that are perpendicular to a second plurality of parallel linearly extending portions. These linearly extending portions may also have different lengths and may extend inward to different locations within an

interior of a wound dressing component. The sensor array portion preferably does not cover the entire wound dressing component, so that gaps are formed between portions of the sensor array. As shown in FIG. **2**, this allows some, and possibly a majority of the wound dressing component to be uncovered by the sensor array. For example, for a perforated wound contact layer as shown in FIGS. **2** and **3**D, the sensor array portion **301** may not block a majority of the perforations in the wound contact layer. In some cases, the sensor array may also be perforated or shaped to match the perforations in the wound contact layer to minimize the blocking of perforations to fluid flow.

FIG. **3**D illustrates an example flexible sensor array incorporated into a perforated wound contact layer **320**. As is illustrated, the sensor array can be sandwiched between two films or wound contact layers. The wound contact layers can have perforations formed as slits or holes as described herein that are small enough to help prevent tissue ingrowth into the wound dressing while allowing wound exudate to flow into the dressing. In some cases, the wound contact layers can have one or more slits that increase flexibility of the wound contact layer with integrated sensor array. In some cases, one of the wound contact layers can have extra cut outs to accommodate the sensors so that they can contact the skin directly.

Connectivity for the sensor array can vary depending on the various sensors and sensor array designs utilized. In some cases, for example as shown in FIG. **3**B, a total of 79 connections can be used to connect the components of the sensor array. The sensor arrays can be terminated in two parallel 40-way 0.5 mm pitch Flat Flexible Cable (FFC) contact surfaces, with terminals on the top surface, designed to be connected to an FFC connector such as Molex 54104-4031.

In some cases, one or more of thermistors, conductivity sensors, SpO2 sensors, or color sensors can be used on the sensor array to provide information relating to conditions of the wound. The sensor array and individual sensors can assist a clinician in monitoring the healing of the wound. The one or more sensors can operate individually or in coordination with each other to provide data relating to the wound and wound healing characteristics.

Temperature sensors can use thermocouples or thermistors to measure temperature. The thermistors can be used to measure or track the temperature of the underlying wound or the thermal environment within the wound dressing. The thermometry sensors can be calibrated and the data obtained from the sensors can be processed to provide information about the wound environment. In some cases, an ambient sensor measuring ambient air temperature can also be used to assist in eliminating problems associated with environment temperature shifts.

Optical sensors can be used to measure wound appearance using an RGB sensor (for example, a red, green, blue, and clear (RGBC) sensor or red, green blue, and white (RGBW) sensor) with an illumination source. In some cases, both the RGB sensor and the illumination source would be pressed up against the skin, such that light would penetrate into the tissue and take on the spectral features of the tissue itself.

Light propagation in tissue can be dominated by two major phenomena, scattering and attenuation. For attenuation, as light passes through tissue, its intensity may be lost due to absorption by various components of the tissue. Blue light tends to be attenuated heavily, whilst light at the red end of the spectrum tends to be attenuated least.

Scattering processes can be more complex, and can have various "regimes" which must be considered. The first aspect of scattering is based on the size of the scattering centre compared with the wavelength of incident light. If the scattering center is much smaller than the wavelength of light, then Rayleigh scattering can be assumed. If the scattering center is on the order of the wavelength of light, then a more detailed Mie scattering formulation must be considered. Another factor involved in scattering light is the distance between input and output of the scattering media. If the mean free path of the light (the distance between scattering events) is much larger than the distance travelled, then ballistic photon transport is assumed. In the case of tissue, scatting events are approximately 100 microns apart—so a 1 mm path distance would effectively randomise the photon direction and the system would enter a diffusive regime.

Ultra bright light emitting diodes (LEDs), an RGB sensor, and polyester optical filters can be used as components of the optical sensors to measure through tissue color differentiation. For example, because surface color can be measured from reflected light, a color can be measured from light which has passed through the tissue first for a given geometry. This can include color sensing from diffuse scattered light, from an LED in contact with the skin. In some cases, an LED can be used with an RGB sensor nearby to detect the light which has diffused through the tissue. The optical sensors can image with diffuse internal light or surface reflected light.

Additionally, the optical sensors can be used to measure autofluorescence. Autoflourescense is used because the tissue is absorbing light at one wavelength, and emitting at another. Additionally, dead tissue may not auto-fluoresce and so this could be a very strong indication as to if the tissue is healthy or not. Due to blue light (or even UV light) having such a short penetration depth, it may be very useful for example to have a UV light with a red sensitive photodiode nearby (or some other wavelength shifted band) to act as a binary test for healthy tissue, which would auto-fluoresce at a very particular wavelength.

Conductivity sensors can be used to determine the difference between living and dead tissue or to show a change in impedance due to a wound being opened up in morbid tissue. Conductivity sensors can include Ag/AgCl electrodes and an impedance analyser. The conductivity sensors can be used to measure the change of impedance of a region of wound growth by measuring the impedance of the surrounding tissue/area. In some cases, the sensor array can utilize conductivity sensors to measure the change in conductivity on perimeter electrodes due to a wound size or wound shape change. In some cases, the conductivity sensors can be used in the wound bed or on the perimeter of the wound.

In some cases, pH changing pads can be used as a pH sensor. A spectrometer and a broadband white light source can be used to measure the spectral response of the pH dye. The illumination and imaging can be provided on the surface of the wound dressing that is in contact with the wound and at the same side as the fluid application, the bottom surface. Alternatively, in some cases, the illumination and imaging source can be provided on the surface of the wound dressing opposite the bottom surface and away from fluid application or the top surface of the dressing.

In some cases, pulse oximetry SpO2 sensors can be used. To measure how oxygenated the blood is and the pulsatile blood flow can be observed. Pulse oximetry measurements work by taking a time resolved measurement of light absorption/transmission in tissue at two different optical wavelengths. When hemoglobin becomes oxygenated, its absorption spectrum changes with regards to non-oxygenated

blood. By taking a measurement at two different wavelengths, one gains a ratio metric measure of how oxygenated the blood is.

The components in the sensor array can be connected through multiple connections. In some cases, the thermistors can be arranged in groups of five. Each thermistor is nominally 10 kΩ, and each group of five has a common ground. There are five groups of thermistors, giving a total of 30 connections. In some cases, there can be nine conductivity terminals. Each conductivity terminal requires one connection, giving a total of 9 connections. In some cases, there can be five SpO2 sensors. Each SpO2 sensor requires three connections, plus power and ground (these are covered separately), giving a total of 15 connections. In some cases, there can be 10 color sensors. Each color sensor comprises an RGB LED and an RGB photodiode. Each color sensor requires six connections, however five of these are common to every sensor, giving a total of 15 connections. Power and ground are considered separately. In some cases, there can be 5 pH sensors. The pH sensors can be a color-change discs, and can be sensed using the color sensors described above. Therefore, the pH sensors require no additional connections. There can be three power rails, and seven ground return signals, giving a total of 10 common connections. In some cases, the sensor array can include 25 thermistor (Murata NCP15WB473E03RC), 9 conductivity terminal, 5 SpO2 (ADPD144RI), 10 RGB LED (such as KPTF-1616RGBC-13), 10 RGB Color Sensor, 10 FET, a printed circuit board (PCB), and an assembly.

A control module can be used to interface with the sensor array. In some cases, the control module can contain a power source, such as one or more batteries, and electronics to drive the sensors. The control module can also log data at appropriate intervals and allow data transfer to an external computing device, such as a personal computer (PC). The control module can be customized to have various features depending on the sensors used in the sensor array and the data collected by the sensors. In some cases, the control module can be comfortable enough and small enough to be worn continuously for several weeks. In some cases, the control module can be positioned near the wound dressing or on the wound dressing. In some cases, the control module can be positioned in a remote location from the wound dressing and accompanying sensor array. The control module can communicate with the sensor array and wound dressing through electrical wires or through wireless communication whether positioned on the dressing, near the dressing, or remote from the wound dressing. In some cases, the control module can be adapted to be utilized with different sensor arrays and can enable easy replacement of the sensor array.

In some cases, the control module can include various requirements and combination of features including but not limited to the features listed in Table 1 below.

TABLE 1

OPTIONAL FEATURES FOR CONTROL MODULE
7 day operation from a single set of batteries
28 day local, non-volatile, storage capacity
Easy to charge, or to replace battery
Wireless link to PC/tablet (such as Bluetooth)
Wired link to PC (optional, micro-USB)
Drive electronics for thermistors
Drive electronics for conductivity sensors
Drive electronics for optical sensors
Drive electronics for SpO2 sensors
Power management
Real Time Clock (RTC) to allow accurate data logging, and correlation with other measurands
Ability to change sample rates and intervals (useful for SpO2) for each sensor
Indication of status via LED, such as (Green: Awake; Flashing green: Charging; Blue: Wireless link established; Flashing blue: Wireless data transfer; Yellow: Wired link established; Flashing yellow: Wired data transfer; Red: Battery low; Flashing red: Battery very low

TABLE 1-continued

OPTIONAL FEATURES FOR CONTROL MODULE

FIG. **3**E illustrates a block diagram **330** of an example control module. The block diagram of the control module includes a conductivity driver box **391** displaying features of the conductivity driver. Box **392** shows the features of the thermistor interface and box **393** shows the features of the optical interface. The control module can include a controller or microprocessor with features similar to those shown in box **394**. Real time clock (RTC), Status LEDs, USB connector, Serial Flash, and Debug Connector can be included as features of the control module as shown in FIG. **3**E.

In some cases, the microprocessor can have one or more of the following features: 2.4 GHz or another suitable frequency radio (either integrated, or external); Supplied Bluetooth software stack; SPI interface; USB (or UART for external USB driver); I2C; 3 channel PWM; 32 GPIO; or 6-channel ADC. In some cases, the device can require at least 48 I/O pins or possibly more due to banking limitations. Bluetooth stack typically requires ~20 kB on-board Flash, so a minimum of 32 kB can be required. In some cases, 64 kB can be required if complex data processing is considered. The processor core can be ARM Cortex M4 or a similar processor core. In some cases, the parts can include ST's STM32L433LC or STM32F302R8, which would require an external radio, or NXP's Kinetis KW range including integrated radio.

In some cases, the control module can include a memory component where the amount of local storage depends on the sample rate and resolution of the sensors. For example, an estimated data requirement of 256 Mb (32 MB) can be met by using a serial Flash device from a number of manufacturers (Micron, Spansion).

The control module can utilize one or more analogue switches. In some cases, analogue switches with good on resistance and reasonable bandwidth can be used. For example, Analog Devices' ADG72 or NXP's NX3L4051HR can be used. Based on the initial system architecture, 8 of these will be required.

The control module can incorporate a power source, such as a battery. For example a 300 mWh/day battery can be used. For 7 days this is 2100 mWh. This could be provided by: a 10 days, non-rechargeable, ER14250 (14.5 mm diameter×25 mm) LiSOCl2 cell; or a 7 days, rechargeable, Li 14500 (14.5 mm diameter×500 mm) Li-Ion.

The control module can incorporate a real time clock (RTC). The RTC can be chosen from any RTC devices with crystal. The control module can also include miscellaneous resistors, capacitors, connectors, charge controllers, and other power supplies.

The PCB of the control module can be a 4-layer board, approximately 50 mm×20 mm, or 25 mm×40 mm. The type of PCB used can be largely driven by connection requirements to sensor array.

The enclosure of the control module can be a two part moulding, with clip features to allow easy access for changing sensor arrays or batteries.

The data collected through the sensor array can be passed through the control module and processed by host software. The software may be executed on a processing device. The processing device can be a PC, tablet, smartphone, or other computer capable of running host software. The processing device executing the software can be in communication with the control module through electrical wires or through wireless communication. In some cases, the software may be configured to provide access to the data held on the control module, but not to perform big-data analysis. The host software can include an interface to the control module via Bluetooth or USB. In some cases, the host software can read the status of control module, download logged data from control module, upload sample rate control to control module, convert data from control module into format suitable for processing by big-data analysis engine, or upload data to cloud for processing by analysis engine.

The software may be developed for PC (Windows/Linux), tablet or smartphone (Android/iOS), or for multiple platforms.

In some cases, a source of negative pressure (such as a pump) and some or all other components of the topical negative pressure system, such as power source(s), sensor(s), connector(s), user interface component(s) (such as button(s), switch(es), speaker(s), screen(s), etc.) and the like, can be integral with the wound dressing. In some cases, the components can be integrated below, within, on top of, or adjacent to the backing layer. In some cases, the wound dressing can include a second cover layer or a second filter layer for positioning over the layers of the wound dressing and any of the integrated components. The second cover layer can be the upper most layer of the dressing or can be a separate envelope that enclosed the integrated components of the topical negative pressure system.

As used herein the upper layer, top layer, or layer above refers to a layer furthest from the surface of the skin or wound while the dressing is in use and positioned over the wound. Accordingly, the lower surface, lower layer, bottom layer, or layer below refers to the layer that is closest to the surface of the skin or wound while the dressing is in use and positioned over the wound.

Wound Therapy System with Multiple Power Sources

FIG. **4** illustrates an example system **400** for providing therapy to a wound. The system **400** includes a controller **402**, a pressure source **404**, a first power source **406**, a second power source **408**, and electronic component(s) **410**, any two or more of which can be electrically coupled with one another. The system **400** can include fewer or more components as desired. For example, in some cases, the system **400** may include one or any combination of two or more of the controller **402**, the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410**. As another example, the system **400** can include one or more additional controllers, pressure sources, power sources, or electronic components.

One or both of the first power source **406** or the second power source **408** can include an energy storage device configured to supply energy. For example, each the first power source **406** or the second power source **408** can be implemented as a battery, a capacitor, a capacitor-battery hybrid, a fuel-cell, or any combination thereof, among other energy storage devices.

One or both of the first power source **406** or the second power source **408** can include a battery. The size, shape, and characteristics of the battery can vary depending on the embodiment. For example, the battery can be one or more of various battery types including, but not limited to, a nickel cadmium battery, a nickel metal hydride battery, a lithium ion battery, a small sealed lead acid battery, an alkaline battery, or other suitable type of battery. Furthermore, the battery can be rechargeable or non-rechargeable.

The battery can be one or more of various shapes or sizes. For example, the battery can include a cylindrical battery, a coin-shaped cell, a rectangular battery, or other battery. Moreover, the battery can have a capacity or a rated voltage or current that is suitable for use in the system **400**. For example, a battery can have a capacity falling within the range of 1 and 50 Watts, can be rated for a voltage falling within the range 1.25 V and 9 V (or more), and can be rated for a current falling within the range of 10 mA to several amps. In some cases, the battery can include multiple batteries, such as a bank of batteries. Each of the multiple batteries can be of the same or a different type, or can have the same or a different capacitance value.

One or both of the first power source **406** or the second power source **408** can include a capacitor. The size, shape, and general characteristics of the capacitor can vary depending on the embodiment. For example, the capacitor can be one or more of various types including, but not limited to, an electrolytic capacitor, a ceramic capacitor, a tantalum capacitor, a polycarbonate capacitor, a polyester capacitor, a silver mica capacitor, a glass dielectric capacitor, a polypropylene capacitor, polystyrene capacitor, or a super capacitor, among other types of capacitors. Furthermore, any of the one or more capacitors can be rechargeable.

The capacitor can have one or more of various capacitance values. For example, the capacitor can have relatively low capacitance values, ranging from 1 pF to a few microfarads. In addition or alternatively, the capacitor can have capacitance values as small as 1,000 pF or as large as 100 μF. Moreover, the capacitor can have capacitance values ranging up to about 1 mF or 1 F (non-limiting examples: 0.015 F, 0.022 F, 0.036 F, 0.047 F, 0.068 F, 0.1 F, 0.22 F, 0.33 F, 0.47 F, 0.7 F, or 0.85 F (+/−a few 10 or 100 mF)). Furthermore, in some implementations, the capacitor have a capacitance value at or exceeding a farad, such as, but not limited to, 1 F, 1.4 F, 1.5 F, 2.2 F, 3 F, 3.3 F, 4 F, 4.7 F, 10 F or more (+/−a few 100 mF). In some cases, the capacitor can include multiple capacitors, such as a bank of capacitors. Each of the multiple capacitors can be of the same or a different type, or can have the same or a different capacitance value.

The capacitor can include a super capacitor. Use of a super capacitor can be advantageous for one or several reasons. For example, in general, a super capacitor, as compared to other types of capacitors, can store more energy per unit volume (for example, 10 to 100 times). Moreover, a super capacitor can generally accept and deliver charge faster than batteries, and can generally tolerate more charge and discharge cycles than rechargeable batteries. In the event of a fault, a capacitor or a super capacitor can be less dangerous than a battery. Furthermore, in some cases, batteries are less suited to provide an impulse or high current than a capacitor or super capacitor.

One or both of the first power source **406** or the second power source **408** can be re-chargeable. For example, in some cases, the first power source **406** or the second power source **408** can be charged prior to, while, or after providing therapy to a wound of a patient. As another example, the first power source **406** or the second power source **408** can be charged prior to, while, or after positioning the wound dressing on the patient. For example, as described herein, one or more of the components of the system **400** can be included in, or supported by, a wound dressing such as wound dressing **100** or wound dressing **155**. Such charging

can be performed wirelessly, such as via inductive charging. In addition or alternatively, such charging can be performed via one or more energy harvesting techniques. One or more indications can be provided to indicate that one or both of the first or second power sources **406** or **408** has been charged, is charging, or has low or no charge. Prior to deployment on a patient, one or both of the first power source **406** or the second power source **408** can be stored without any power or configured with less than a full charge.

The electronic component(s) **410** can include one or more of various components of the system **400**. For example, the electronic component(s) **410** can include, but are not limited to, wireless communication circuitry, one or more sensors (non-limiting examples: a pressure sensor, a nanosensor, a thermistor, a conductivity sensor, an SpO2 sensor, a pH sensor, a color sensor, an optical sensor, or electrical stimulator or stimulation component (non-limiting example: an electrode), or other sensing device), a real time clock (RTC), an LED (non-limiting example: a status LED), a user interface component (non-limiting examples: button(s), switch(es), speaker(s), screen(s), etc.), or the like. In some cases, although illustrated as separate in FIG. **4**, the electronic component(s) **410** can even include the controller **402** or the pressure source **404**, as well as one or more or all other electrical components of the system **400**.

In some cases, the electronic component(s) **410** can include one or more active components, such as those which possess gain and can provide energy to the system **400** (non-limiting examples: a transistor, a battery, an amplifier, an integrated circuit, or the like.) In some cases, the electronic component(s) **410** can include one or more passive components, such as those which generally do not amplify or energize the energy of the signal associated with them (non-limiting examples: a resistor, an inductor, a capacitor, a diode, an LED, or the like).

The controller **402** can have features or capabilities similar to those of a controller or processor described herein, such as those features shown in, or described with respect to, box **394** of FIG. **3**E. The controller **402** can be in electrical communication with or configured to control or operate any combination of the pressure source **404**, first power source **406**, second power source **408**, or the electronic component(s) **410**.

Furthermore, the controller **402** can monitor or determine an occurrence of one or more conditions associated with the system **400**, such as one or more conditions associated with the first power source **406** or the second power source **408**. Responsive to a first condition, the controller **402** can cause the first power source **406** to power the electronic component(s) **410** or can cause the second power source **408** to discontinue its powering of the electronic component(s) **410**, or a combination thereof. Responsive to a second condition, the controller **402** can cause the second power source **408** to power the electronic component(s) **410** or can cause the first power source **406** to discontinue its powering of the electronic component(s) **410**, or a combination thereof.

The pressure source **404** can provide negative pressure to a wound dressing that is positioned in contact with a wound of a patient. The pressure source **404** can include a pump, such as, without limitation, a rotary diaphragm pump or other diaphragm pump, a piezoelectric pump, a peristaltic pump, a piston pump, a rotary vane pump, a liquid ring pump, a scroll pump, a diaphragm pump operated by a piezoelectric transducer, or any other suitable pump or micropump or any combination thereof. In some cases, the pressure source **404** can be an example of one or more of a pump as described herein.

FIG. **5** illustrates a system **500**, which is an example configuration of the system **400** of FIG. **4**. As described with respect to FIG. **4**, the system **400** can include the controller **402**, the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410**.

Any of the controller **402**, the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410** can be separate such that the system **500** includes two or more separate housings. For example, as illustrated in FIG. **5**, the controller **402** and the pressure source **404** can be part of a wound dressing apparatus **530**, while the first power source **406**, the second power source **408**, or the electronic component(s) **410** can be part of a wound dressing **520**, which can be an example of the wound dressing **100** of FIGS. **1**C-**1**E or the wound dressing **155** of FIG. **1**B. Any of the separate housings can be placed apart from each other. Furthermore, one or more elements of each of the separate housings can communicate with one or more elements of the other separate housing via a wireless or wired connection.

Some or all of the components of the system **400** can be part of (non-limiting examples: integrated with, attached to, or embedded in) the wound dressing **520** (such as the wound dressing **100** of FIGS. **1**C-**1**E or the wound dressing **155** of FIG. **1**B). For example, in the illustrated example of FIG. **5**, the first power source **406**, the second power source **408**, and the electronic component(s) **410** are part of the wound dressing **520**. However, it will be understood that any combination of the controller **402**, the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410** can be part of the wound dressing **520**.

Some or all of the components of the system **400** can be part of (non-limiting examples: integrated with, attached to, or embedded in) the wound dressing apparatus **530** that can be different from the wound dressing **520**. For example, in the illustrated example of FIG. **5**, the controller **402** and the pressure source **404** are part of the wound dressing apparatus **530**. However, it will be understood that any combination of the controller **402**, the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410** can be part of the wound dressing apparatus **530**.

As one example, the first power source **406** can include a battery and the second power source **408** can include a capacitor. The second power source **408** can act as a back-up or supplemental power supply to the first power source **406**. For example, within a short time window of the first power source **406** dying or otherwise failing to satisfy a threshold battery charge, the system **400** can transfer at least some of the electrical load of the system **400** to the second power source **408** so that the second power source **408** provides power in addition to or in place of the first power source **406**. As another example, within a short time window of the first power source **406** is experiencing a high energy demand, the system **400** can supplement at least some of the electrical load of the system **400** with power from the second power source **408** so that the second power source **408** provides power in addition to the first power source **406**.

In some circumstances, it can be more important that certain components of the system **500** remain powered, while it may not be as important for other components to remain powered. Accordingly, in some cases, such as if one or both of the first power source **406** or the second power source **408** do not satisfy a threshold power, the system **500** can provide power to some components, while leaving other

components unpowered, at least temporarily. In some cases, one or more of the components of the system (for example, any one or more of the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410**) can be associated with a priority level.

As an example, the first power source **406** can provide power to all or most of the components of the system **500**. Furthermore, a real-time clock of the system **400** (which may be maintained by the controller **402**) can be associated with a first priority level, while other components of the system **500** (for example, any one or more of the pressure source **404**, the first power source **406**, the second power source **408**, or the electronic component(s) **410**) can be associated with one or more second priority levels. As the first power source **406** reduces in power such that it does not satisfy a threshold power, the system **500** can remove power from each of the components having the second priority level, while continuing to power the components of the first priority level. By discontinuing its provision of power to the second priority level components, the first power source **406** can conserve power for use in powering the first priority level components. Similarly, in some cases, the second power source **408** can act as a back up to the first power source **406**. In some cases, the second power source **408** can provide backup power to the first priority level components, while not providing backup power to the second priority level components. In some cases, the second power source **408** can provide backup power to both the first priority level components and the second priority level components for a duration of time (for example, one second, one minute, five minutes, one hour, one day, or a shorter or longer duration) and then provide backup power to the first priority level components while not providing backup power to the second priority level components.

Some components of the system **400** can be better suited for charging or powering by the first power source **406**. Moreover, other components of the system **400** can be better suited for charging or powering by second power source **408**. For example, components (such as an electrode) that function using a large rush of electrical current, may be better suited for a capacitor. Accordingly, a capacitor of the second power source **408** can charge some components (for example, some, but not all, of the electronic component(s) **410**) and a battery of the first power source **406** can charge different components (for example, different components of the electronic component(s) **410**). In some cases, at least some components of the system **400** can be charged or powered by both the first power source **406** and the second power source **408**, simultaneously or at distinct time intervals.

Continuing with the example, the system **400** can offer the benefits of both a battery and a capacitor. For example, a battery can provide advantages over a capacitor because a battery can have a greater energy density than a capacitor, among other things. Similarly, a capacitor can provide advantages over a battery because a capacitor can generally accept and deliver charge faster than a battery, can tolerate more charge and discharge cycles than rechargeable batteries, can be less dangerous in the event of a fault, and can provide an impulse or high current, among other things. Accordingly, by including both a battery (for example, in the first power source **406**) and a capacitor (for example, in the second power source **408**), the system **400** can offer the benefits of both a battery and a capacitor.

The second power source **408** can be rechargeable and the first power source **406** can charge the second power source **408**. For example, while the first power source **406** is providing power to one or more components of the system **400**, the first power source **406** can also provide power to the second power source **408**. Alternatively, in some cases, one or more other components that are different from the first power source **406**, such as a coin cell, can charge the second power source **408**. Similarly, the first power source **406** can be rechargeable and the second power source **408** can charge the first power source **406**.

Power Supply Control in Wound Monitoring or Therapy

FIG. **6** is a flow diagram illustrative of an example of a routine **600** for monitoring or providing therapy to a wound. The elements outlined for routine **600** can be implemented by a system (such as the systems **102**, **400**, or **500**), one or more computing devices or components that are associated with a system (non-limiting example: controller **402**), a wound monitoring or therapy apparatus, or the like. For ease of reference, the routine **600** has been described as being performed by system **500**. Furthermore, for convenience, the system **500** and the routine **600** are described in the context of the first power source **406** including a battery and the second power source **408** including a capacitor. However, other examples or configurations are possible.

At block **602**, the battery of the first power source **406** supplies power to the electronic component(s) **410**. The battery of the first power source **406** can electrically connect to the electronic component(s) **410**. For example, so that the battery of the first power source **406** can supply power to the electronic component(s) **410**, the controller **402** can electrically connect the battery of the first power source **406** to the electronic component(s) **410** with a switch or other component that makes or breaks an electrical connection between the battery of the first power source **406** and the electronic component(s) **410**.

In some cases, at block **602**, the electronic component(s) **410** may receive power from the battery of the first power source **406** and may not simultaneously receive power from another source of power, such as the capacitor of the second power source **408**. In this way, the first power source **406** can supply power to the electronic component(s) **410** in place of the second power source **408**. For example, the battery of the first power source **406** and the capacitor of the second power source **408** can power the electronic component(s) **410** at distinct time intervals, such that the first power source **406** does not provide power to the electronic component(s) **410** while the second power source **408** provides power to the electronic component(s) **410**.

The controller **402** can cause the second power source **408** to discontinue supplying power to one or more of the electronic component(s) **410**. For example, prior to block **602**, the second power source **408** can be electrically connected and supplying power to the electronic component(s) **410**. At block **602**, the controller **402** can electrically disconnect the second power source **408** from the one or more of the electronic component(s) **410** with a switch or other component that makes or breaks an electrical connection between the second power source **408** and the electronic component(s) **410** so that the second power source **408** no longer supplies power to the electronic component(s) **410**.

In some cases, at block **602**, the electronic component(s) **410** simultaneously receive power from the first power source **406** and another source of power, such as the second power source **408**. For example, the battery of the first power source **406** and the capacitor of the second power source **408** can provide power to the electronic component(s) **410** at one or more overlapping time intervals. The battery of the first power source **406** can, for instance, supply power to the electronic component(s) **410** while the capacitor of the

second power source **408** is in a discharged state or otherwise includes a charge that does not satisfy a capacitor charge threshold.

The first power source **406** can power the electronic component(s) **410** and one or more other elements of the system **500**, such as the controller **402**, pressure source **404**, capacitor of the second power source **408**, or any combination thereof. For example, the battery of the first power source **406** can charge the capacitor of the second power source **408** while the battery of the first power source **406** provides power to the electronic component(s) **410**.

At block **604**, if a first condition is not satisfied, then the routine **600** returns to block **602**, where the first power source **406** continues to power the electronic component(s) **410**. On the other hand, if a first condition is satisfied, then the routine **600** proceeds to block **606**.

The first condition can correspond to one or more characteristics or features of the first power source **406**. As examples, the first condition can correspond to a capacity of the battery of the first power source **406**, an amount of energy stored by the battery of the first power source **406**, a voltage of the battery of the first power source **406**, a temperature of the battery of the first power source **406**, or a combination thereof. For instance, if the first condition corresponds to the voltage of the battery of the first power source **406**, the first condition can be satisfied if the battery voltage satisfies a threshold battery voltage, or may not be satisfied if the battery voltage does not satisfy the threshold battery voltage.

Additionally or alternatively, the first condition can correspond to one or more characteristics or features of the second power source **408**. As examples, the first condition can correspond to a capacitance of the capacitor of the second power source **408**, a charge of the capacitor of the second power source **408**, a voltage across the capacitor of the second power source **408**, a temperature of the capacitor of the second power source **408**, or a combination thereof. For instance, if the first condition corresponds to the charge of the capacitor of the second power source **408**, the second condition can be satisfied if the charge of the capacitor of the second power source **408** charge satisfies a threshold charge, or may not be satisfied if the charge of the capacitor of the second power source **408** does not satisfy the threshold charge.

The controller **402** can monitor the one or more characteristics or features corresponding to the first condition to determine an occurrence of the first condition (for example, first condition satisfied) based at least on a comparison of a value associated with the monitored the characteristics or features to the threshold. Based on a determination that the threshold is satisfied, the controller **402** can cause the routine **600** to transition to block **606**.

At block **606**, the second power source **408** supplies power to one or more of the electronic component(s) **410**. As described herein, the second power source **408** can electrically connect to the one or more of the electronic component(s) **410**. For example, so that the capacitor of the second power source **408** can supply power to the one or more of the electronic component(s) **410**, the controller **402** can electrically connect the capacitor of the second power source **408** to the electronic component(s) **410** with a switch or other component that makes or breaks an electrical connection between the capacitor of the second power source **408** and the electronic component(s) **410**.

In some cases, at block **606**, the electronic component(s) **410** may receive power from the second power source **408** and may not simultaneously receive power from the first power source **406**. The second power source **408** can moreover supply power to the electronic component(s) **410** in place of the first power source **406**. The controller **402** can, for instance, cause the first power source **406** to discontinue supplying power to the electronic component(s) **410** with a switch or other component that makes or breaks an electrical connection between the first power source **406** and one or more of the electronic component(s) **410** so that the first power source **406** no longer supplies power to the one or more of the electronic component(s) **410**. The second power source **408** can in some cases supply power to the electronic component(s) **410** while the first power source **406** is in a discharged state or otherwise includes a voltage that does not satisfy a threshold voltage.

Additionally or alternatively, at block **606**, the electronic component(s) **410** receive power from the second power source **408** and another source of power, such as the first power source **406**. In some cases, at block **606**, the first power source **406** can supply reduced power (as compared to block **602**) to the electronic component(s) **410**.

In some cases, at block **606**, the second power source **408** may supply power to the electronic component(s) **410** and may not supply power to any of the controller **402**, pressure source **404**, or battery of the first power source **406**. Alternatively, in some cases, the second power source **408** supplies power to the electronic component(s) **410** and one or more other elements of the system **500**, such as the controller **402**, the pressure source **404**, the battery of the first power source **406**, or any combination thereof. For example, the capacitor of the second power source **408** can charge the battery of the first power source **406** while the capacitor of the second power source **408** provides power to the electronic component(s) **410**.

At block **608**, if a second condition is not satisfied, then the routine **600** returns to block **606**, where the second power source **408** continues to power the electronic component(s) **410**. On the other hand, if a second condition is satisfied, then the routine **600** proceeds to block **608**.

The second condition can correspond to one or more characteristics or features of the first power source **406**. As examples, the second condition can correspond to a capacity of the battery of the first power source **406**, an amount of energy stored by the battery of the first power source **406**, a voltage of the battery of the first power source **406**, a temperature of the battery of the first power source **406**, or a combination thereof. For instance, if the second condition corresponds to the voltage of the battery, the first condition can be satisfied if the battery voltage satisfies a threshold battery voltage, or may not be satisfied if the battery voltage does not satisfy the threshold battery voltage.

The second condition can correspond to one or more characteristics or features of the second power source **408**. As examples, the second condition can correspond to a capacitance of the capacitor of the second power source **408**, a charge of the capacitor of the second power source **408**, a voltage across the capacitor of the second power source **408**, a temperature of the capacitor of the second power source **408**, or a combination thereof. For instance, if the second condition corresponds to the charge of the capacitor of the second power source **408**, the second condition can be satisfied if the charge of the capacitor of the second power source **408** charge satisfies a threshold charge, or may not be satisfied if the charge of the capacitor of the second power source **408** does not satisfy the threshold charge.

The controller **402** can monitor the one or more characteristics or features that correspond to the second condition to determine an occurrence of the second condition (for

example, second condition satisfied) based at least on a comparison of a value associated with the monitored the characteristics or features to a threshold. Based on a determination that the threshold is satisfied, the controller **402** can cause the routine **600** to end or transition to block **602**.

The various blocks described herein with respect to routine **600** can be implemented in a variety of orders, and that the routine **600** can implement one or more of the blocks concurrently or change the order, as desired. For example, the routine **600** can begin at block **606** rather than block **602**. Furthermore, fewer, more, or different blocks can be used as part of the routine **600**. For example, the routine **600** can omit certain blocks, such as, but not limited to, blocks **602**, **604**, **606**, or **608**. For example, the routine **600** can end responsive to a determination that the first condition is satisfied (block **604**) or the second condition is satisfied (block **608**).

The first power source **406** and the second power source **408** can power the electronic component(s) **410** at distinct time intervals, such that the first power source **406** does not power the electronic component(s) **410** while the second power source **408** powers the electronic component(s) or the second power source **408** does not power the electronic component(s) **410** while the first power source **406** powers the electronic component(s) **410**. Alternatively, the first power source **406** and the second power source **408** can power the electronic component(s) **410** at overlapping time intervals, such that the first power source **406** can power the electronic component(s) **410** while the second power source **408** powers the electronic component(s) **410**.

The first power source **406** can include a power source other than, or in addition to, a battery. For example, the first power source **406** can include a capacitor. Similarly, the second power source **408** can include a power source other than, or in addition to, a capacitor. For example, the second power source **408** can include a battery, such as a coin cell. Moreover, the subset of electronic component(s) **410** powered by the battery of the first power source **406** at block **602** can be different from the subset of electronic component(s) **410** powered by the capacitor of the second power source **408** at block **606**. For example, the battery can power at least some electronic component(s) at block **606**. Similarly, the capacitor of the second power source **408** can power at least some electronic component(s) at block **602**.

Other Variations

Any value of a threshold, limit, duration, etc. provided herein is not intended to be absolute and, thereby, can be approximate. In addition, any threshold, limit, duration, etc. provided herein can be fixed or varied either automatically or by a user. Furthermore, as is used herein relative terminology such as exceeds, greater than, less than, etc. in relation to a reference value is intended to also encompass being equal to the reference value. For example, exceeding a reference value that is positive can encompass being equal to or greater than the reference value. In addition, as is used herein relative terminology such as exceeds, greater than, less than, etc. in relation to a reference value is intended to also encompass an inverse of the disclosed relationship, such as below, less than, greater than, etc. in relations to the reference value. Moreover, although blocks of the various processes may be described in terms of determining whether a value meets or does not meet a particular threshold, the blocks can be similarly understood, for example, in terms of a value (i) being below or above a threshold or (ii) satisfying or not satisfying a threshold.

Features, materials, characteristics, or groups described in conjunction with a particular aspect, embodiment, or example are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features or steps are mutually exclusive. The protection is not restricted to the details of any foregoing embodiments. The protection extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of protection. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms. Furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made. Those skilled in the art will appreciate that in some embodiments, the actual steps taken in the processes illustrated or disclosed may differ from those shown in the FIGS. Depending on the embodiment, certain of the steps described above may be removed, others may be added. For example, the actual steps or order of steps taken in the disclosed processes may differ from those shown in the FIG. Depending on the embodiment, certain of the steps described above may be removed, others may be added. For instance, the various components illustrated in the FIGS. may be implemented as software or firmware on a processor, controller, ASIC, FPGA, or dedicated hardware. Hardware components, such as controllers, processors, ASICs, FPGAs, and the like, can include logic circuitry. Furthermore, the features and attributes of the specific embodiments disclosed above may be combined in different ways to form additional embodiments, all of which fall within the scope of the present disclosure.

Although the present disclosure includes certain embodiments, examples and applications, it will be understood by those skilled in the art that the present disclosure extends beyond the specifically disclosed embodiments to other alternative embodiments or uses and obvious modifications and equivalents thereof, including embodiments which do not provide all of the features and advantages set forth herein. Accordingly, the scope of the present disclosure is not intended to be limited by the specific disclosures of preferred embodiments herein, and may be defined by claims as presented herein or as presented in the future.

Conditional language, such as "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements, or steps. Thus, such conditional language is not generally intended to imply that features, elements, or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, or steps are included or are to be performed in any particular embodiment. The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means

one, some, or all of the elements in the list. Further, the term "each," as used herein, in addition to having its ordinary meaning, can mean any subset of a set of elements to which the term "each" is applied.

Conjunctive language such as the phrase "at least one of X, Y, and Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require the presence of at least one of X, at least one of Y, and at least one of Z.

Language of degree used herein, such as the terms "approximately," "about," "generally," and "substantially" as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms "approximately", "about", "generally," and "substantially" may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of the stated amount. As another example, in certain embodiments, the terms "generally parallel" and "substantially parallel" refer to a value, amount, or characteristic that departs from exactly parallel by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or 0.1 degree.

The scope of the present disclosure is not intended to be limited by the specific disclosures of preferred embodiments in this section or elsewhere in this specification, and may be defined by claims as presented in this section or elsewhere in this specification or as presented in the future. The language of the claims is to be interpreted broadly based on the language employed in the claims and not limited to the examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive.

What is claimed is:

1. A system for providing therapy to a wound, the system comprising:

a pressure source configured to provide negative pressure to a wound dressing positioned over a wound;

one or more controllers configured to operate the pressure source and communicate with a first set of a plurality of electronic components and a second set of the plurality of electronic components;

a first battery configured to provide power to the first set of the plurality of electronic components; and

a second power source comprising a capacitor configured to store energy and further configured to provide power to the second set of the plurality of electronic components, wherein the second set of the plurality of electronic components operates using a greater amount of electric current than the first set of the plurality of electronic components,

wherein the first set of the plurality of electronic components does not receive power from the second power source and the second set of the plurality of electronic components does not receive power from the first battery during a first time interval, and

wherein the one or more controllers are configured to, responsive to a first condition, cause the first battery and the second power source to provide power to the first set of the plurality of electronic components during a second time interval.

2. The system of claim **1**, wherein the first condition corresponds to a capacity of the first battery.

3. The system of claim **1**, wherein the one or more controllers are configured to determine an occurrence of the first condition from a comparison of a value to a threshold, the value being indicative of a capacity of the first battery.

4. The system of claim **1**, wherein the first set of the plurality of electronic components comprises at least one of a clock, a wireless communications device, a sensor, or an electrical stimulator.

5. The system of claim **1**, wherein the first set of the plurality of electronic components comprises a sensor configured to be positioned proximate the wound and provide measurement data to the one or more controllers, the measurement data being usable by the one or more controllers to monitor healing of the wound.

6. The system of claim **1**, wherein the first set of the plurality of electronic components is supported by the wound dressing.

7. The system of claim **1**, wherein at least one of the pressure source, the one or more controllers, the second power source, or the first battery is supported by the wound dressing.

8. The system of claim **1**, wherein the second power source is configured to be charged by a power source other than the first battery.

9. The system of claim **8**, wherein the power source is a coin cell.

10. The system of claim **1**, wherein the first battery is configured to provide power to at least one of the pressure source or the one or more controllers.

11. The system of claim **1**, wherein the one or more controllers are configured to cause the second power source to provide power to the first set of the plurality of electronic components responsive to a capacity of the first battery not satisfying a threshold charge level indicative of a sufficient charge.

12. The system of claim **1**, wherein the second power source is configured to be charged by the first battery.

13. The system of claim **1**, further comprising an indicator configured to provide indication that at least one of the first battery or the second power source has been fully charged or is being charged.

14. The system of claim **1**, wherein the first battery and the second power source are supported by the wound dressing.

15. The system of claim **1**, wherein the one or more controllers are configured to, responsive to a power demand of the first set of the plurality of electronic components satisfying a demand threshold indicative of a high energy demand, cause the second power source to provide power to the first set of the plurality of electronic components along with the first battery during the second time interval.

16. The system of claim **1**, wherein the second power source comprises a supercapacitor.

17. The system of claim **1**, wherein the second set of the plurality of electronic components comprises one or more electrodes.

18. The system of claim **1**, wherein the one or more controllers are further configured to, responsive to a second condition, cause the first set of the plurality of electronic components to be powered by the first battery and not the second power source, the second condition comprising the first battery satisfying a threshold power level indicative of a sufficient charge or a power demand of the first set of the plurality of electronic components no longer satisfying a demand threshold indicative of a high energy demand.

19. The system of claim **1**, wherein the first condition comprises at least one of a capacity of the first battery, an amount of energy stored by the first battery, a voltage of the first battery, or a temperature of the first battery.

20. The system of claim **1**, wherein the first set of the plurality of electronic components comprises a real-time clock.

21. The system of claim **1**, wherein a first electronic component of the first set of electronic components is associated with a first priority level and a second electronic component of the first set of electronic components is associated with a second priority level lower than the first priority level, and wherein the one or more controllers are further configured to, responsive to a capacity of the first battery satisfying a threshold indicative of a sufficient charge, disconnect the first battery from the second electronic component.

* * * * *